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Workshop on

EFFECTS OF ENVIRONMENTAL REGULATION ON INDUSTRIAL COMPLIANCE COSTS AND TECHNOLOGICAL INNOVATION

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221

Summary and Papers

NATIONAL SCIENCE FOUNDATION
Directorate for Scientific, Technological, and International Affairs
Division of Policy Research and Analysis

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Workshop on

Effects of Environmental Regulation on Industrial Compliance Costs and Technological Innovation

(Summary and Papers)

Washington, D.C.
September 10-11, 1981

National Science Foundation
Division of Policy Research and Analysis
Advanced Technologies and Resources Policy Group

FOREWORD

Major attention has been focused on pressures for and various initiatives advanced for regulatory reform in the United States. The case for regulatory reform rests on the perception held by many that economic performance, technological innovation, market structure, international competitiveness, and other economic and social factors are being negatively influenced by excessive or misdirected governmental regulatory activities.

The Reagan Administration has proposed a vigorous program of regulatory relief, overseen by a Presidential Task Force headed by Vice President Bush. Parts of the program are being implemented by the Office of Management and Budget (OMB) pursuant to Executive Order 12291 ("Federal Regulation") of February 17, 1981 and other directives such as the Paperwork Reduction Act.

Executive Order 12291 calls upon Executive Branch agencies to prepare regulatory impact analyses of proposed federal regulations as well as of existing regulations to assure that cost-effective approaches are utilized in attaining regulatory objectives. At OMB's request, the Advanced Technologies and Resources Policy Group* of the National Science Foundation has undertaken a program of studies on Environmental Regulation under my direction.

The first major component of this NSF program was a workshop, which was held September 10-11, 1981 in Washington, D.C. Participants included government officials, researchers, and representatives of industry and environmental organizations. Five research papers were originally commissioned, prepared, formally reviewed, revised, and then presented and discussed at the workshop. This volume contains three of the workshop papers, a summary of the workshop by its moderator, selected quotations from the edited proceedings of the workshop, and a list of participants. A companion volume (PRA Report 83-9) contains the edited verbatim proceedings of the workshop.

Richard E. Morrison
Senior Policy Analyst
Advanced Technologies and
Resources Policy Group

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* At the time of the request the name of the Group was the Environment, Energy, and Resources Group, and all textual references to the Group are to its original name. The Group was renamed the Advanced Technologies and Resources Policy Group effective January 10, 1983.

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

PREFACE

The Advanced Technologies and Resources Policy Group of the National Science Foundation's Division of Policy Research and Analysis has conducted a series of workshops in response to interest expressed by the Executive Office of the President. These workshops have assessed Federal policy options relating to selected environment, energy, natural resource, and information technology issues.

Each workshop was structured to allow intensive discussion of an identified set of issues that impact Federal policies and programs. Initially, three to five papers were commissioned for each workshop from experts with a variety of backgrounds, experience, and constituencies. First draft papers were revised in light of reviews by other experts and interested parties from government, private industry, environmental, labor, and consumer organizations, research groups, and the academic community. The revised papers and reviewers' comments were then aired at a workshop attended by the authors, reviewers, and a variety of Federal policymakers. Areas of agreement and disagreement were illuminated and sharpened by the discussants. Finally, the papers were further revised for publication based on workshop discussions.

This document, prepared by National Science Foundation staff, contains three of the papers and a summary of a workshop on Effects of Environmental Regulation on Industrial Compliance Costs and Technological Innovation.

Frank L. Huband
Group Leader
Advanced Technologies and
Resources Policy Group

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I. SUMMARY

Richard N.L. Andrews*

Purpose of the Workshop

The purpose of the workshop was to consider the effects of environmental regulation on industrial compliance costs, and on technological innovation.

The U.S. Office of Management and Budget (OMB) has authority to oversee all major regulatory activity of the Federal Government under Executive Order 12291 ("Federal Regulation"), issued February 17, 1981. This Executive Order calls on Executive Branch agencies to prepare regulatory impact analyses of proposed Federal regulations as well as of existing regulations, to assure that cost-effective approaches are used. It also authorizes OMB to set up a control system. This workshop aimed to help OMB and the agencies with these tasks, by bringing together and evaluating the existing methods of estimating costs, identifying what needs to be known, and exploring related issues that must be addressed in designing such a central control system.

The case for regulatory reform is based on the view held by many that some Federal Government regulations impose unnecessary or undesirable costs on the American economy, and that they reduce efficiency and equity. Many also believe that economic performance, technological innovation, market structure, international competitiveness, and other economic and social factors are negatively influenced by excessive, misdirected, or inconsistent governmental regulations.

The Administration is pursuing a program of regulatory relief, overseen by a Presidential Task Force headed by Vice President Bush, and implemented by OMB under Executive Order 12291 and other directives, such as the Paperwork Reduction Act.

Although there is a pressing demand to measure the costs and benefits of regulation, there is an equally pressing need to address the many uncertainties and problems involved in the development and implementation of regulations.

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*Professor of Environmental Sciences and Engineering, and Director, Institute for Environmental Studies, University of North Carolina.

The Bottom Line: More Questions Than Answers

The workshop papers and discussion described and evaluated available techniques for measuring the cost of environmental regulation, and considered whether they overestimate or underestimate costs. However, the upshot of the workshop was that many questions remain unanswered, and many key decisions need to be made.

Workshop participants agreed that there are gaps in data and a lack of acceptable methodology to provide valid cost estimates for individual regulations, industrial sectors, or the economy as a whole. They concluded that estimation of the cost of environmental regulation is still in the experimental stage, as is the estimation of benefits.

The workshop discussions spanned a wide range of issues, including not only the specific question of how to measure costs of regulation, but also an explanation of the assumptions and larger questions that OMB needs to address before the estimators can do their work.

This summary reports on assumptions and decisions that need to be clarified in order for OMB to focus the cost estimation task more clearly. It then covers four areas that were central to the workshop discussions:

1. Can existing methods provide reliable estimates of the costs of particular regulations?
2. Do these methods tend to overestimate or underestimate regulatory costs?
3. Can the aggregate costs of Government regulation be managed?
4. What are the implications for those charged with implementing a central regulatory control system?

Need to Focus the Task More Clearly

Several decisions should be made in order to design a cost estimation system. Technical experts need more information about these three questions in order to proceed with methods for cost estimation.

Which Kinds of Regulations Should Be Considered? Environmental regulations differ in approach and in the object of the control, and they impose different kinds of costs. For example, a procedural regulation imposes primarily administrative overhead costs; a treatment technology requirement imposes primarily capital and operating costs; and an effluent quality standard or factor price surcharge simply imposes a new constraint on process engineering and managerial strategies, the actual cost of which may vary widely depending on what adjustments are made (and there may be a net benefit). In developing cost estimate methodology, it is important to distinguish among different types of regulations and their effects.

Should We Measure Private Costs or Social Costs? Most reporting of the "costs of regulation" has adopted the viewpoint of the regulated industry--measuring the costs of pollution control to the domestic auto or steel industry, or of bottle recycling laws to the beverage industry, or of licensing requirements to the electric utility industry. These costs are real to the firms in question, and in some cases they may also be unprofitable, ineffective, or unfair. Taken alone, however, these costs are not necessarily costs to the national economy or to American society as a whole, which are the primary concern of Government decisions. Several factors distinguish private costs from social costs:

- First, the costs to particular producers may or may not provide useful information about costs to consumers, workers, investors, or even to an industry as a whole.
- Second, they ignore transfer payments--such as costs to one firm of buying pollution control equipment from another--which from an overall point of view may leave the economy just as efficient as it was, or more so.
- Third, they ignore the costs of previous externalities, such as the costs of pollution to the victims, which may be reduced by the firm's expenditures for pollution control.

In short, some regulations impose costs on specific polluters that are also net costs to the overall economy and society, but one cannot make such claims from analysis of industrial compliance costs alone, nor can we derive social costs by simply adding up all the costs claimed by all the regulated firms.

What Are the Purpose and Focus of the Cost Estimates? The issues involved in compliance cost estimation may vary substantially depending on whether the purpose of the analysis is

1. A review of an existing regulation,
2. A projection of the impact of a proposed regulation,
3. A review of the effect of multiple regulations on a particular firm or industry, or
4. A review of the effects of regulations in general (or even of environmental or health and safety regulations in general) on the overall economy.

Most regulatory analyses so far have measured the effects of a proposed regulation. The Vice President's Task Force on regulatory relief has focused on reviewing existing regulations. Current proposals for "regulatory budgets" appear to fall into either the third or fourth category, though it is not yet clear which.

It was frequently unclear during the workshops, and perhaps is unclear generally, which of these four purposes OMB intends to pursue. If OMB identifies the likely approach, then its associated methods and problems can be addressed.

Can Existing Methods Provide Reliable Estimates of the Industrial Compliance Costs of Particular Regulations?

The two main methods in use today to measure the cost of a regulatory requirement are engineering cost estimation and use of a "model plant" to represent common practice in a particular industry or subindustry. Two alternative methods--engineering process models and econometric models--have been suggested, but they have not yet been widely tested for this purpose, they can be costly, and they require a great deal of data.

Another method used more recently is the ad hoc review of the most easily measured costs of regulations that are considered particularly costly; this method is less systematic and complete than the others, but it can be an inexpensive and quick way to address pressing problems.

Existing Methods Raise Technical Problems. All of the existing methods raise questions and problems. Cost estimation methods and assumptions vary substantially among agencies and industries. Many of these variations are legitimately related to differences in factual circumstances or in purpose of the analysis.

Definition of Costs. Studies vary in their definitions of costs. The categories of costs can include direct administrative, capital, and operating costs or can expand to include opportunity costs and changes in management decision and investment patterns, which are harder to measure. Studies also vary in whether they consider incidence of costs to regulated producers, to consumers, or to the economy as a whole (a measure of net efficiency).

Assumptions Vary. Other technical problems include variations in assumptions, and the difficulty of predicting key economic changes. Different cost estimation methods and cost indicators are used in different industries and for different purposes. There is no single "correct" method for all purposes.

Also, different firms, industries, and agencies use substantially different assumptions for key variables such as interest rates, time horizons, depreciation periods, inflation, competitor behavior, price elasticity of demand, and cost of factor inputs. Regulatory cost comparisons may not be possible without standardizing some of these assumptions.

Furthermore, it is difficult to predict future stability or change in regulatory requirements and in vigor of enforcement, although these are important factors in estimating actual compliance costs. Technological innovation is also difficult to predict, and conventional assumptions may underestimate such changes and thus overestimate future costs.

Attribution of Costs. Many costs are difficult to attribute to a particular regulation, especially when there are multiple regulations on the same and related subjects by several agencies and levels of Government, and when compliance costs are influenced by the industry's own actions to increase profits, market share, or favorable image. In principle, the best responses to regulations are those whose costs are so well integrated with the firm's other opportunities and constraints that they are fully joint costs. (This also suggests that any control system which encourages separable accounting of compliance costs may tend to encourage the worst rather than the best responses.) In particular, costs of process changes are far more difficult to attribute to regulations than are end-of-pipe add-ons. Certain administrative overhead expenses, such as an enlarged legal department, may be required by regulation in general but not by any particular regulation.

For similar reasons, it is hard to establish a baseline against which to assess the effect of a regulation, since such a baseline requires difficult assumptions about what would happen in the absence of the regulation. It is also difficult (but important) to determine what costs are due to regulation per se, and which are due to regulatory instability--for instance, when new and unexpected requirements are added after investments have already been made to comply with previous ones, or when regulatory requirements are removed after some firms have sunk control costs into compliance. Furthermore, some costs can be attributed not to a particular regulation but to overlaps, inconsistencies, or redundancies among regulations.

Reliability of Data. Most available data on compliance costs come either from voluntary submissions by the regulated industries, or from estimates developed by the regulatory agencies. Both sources are open to charges of self interest, with industry tending to attribute as many costs as possible to the regulation, and agencies treating compliance costs as the residual after all possible attributions have been made to other factors.

Both industries and agencies tend to ignore--or to make widely divergent assumptions about--cost elements that are widely dispersed or otherwise difficult to measure, such as effects on technological innovation, capital investment, and inflation.

Voluntary submissions may be more apt to come from those firms that feel most burdened by compliance costs, and thus be unrepresentative of the industry as a whole.

"Model plant" analyses may also produce unreliable estimates, either because they are skewed towards "best" or "worst" cases, or because they are unable to represent industries with several different processes or with capital facilities of very different ages and efficiencies.

There is now no system of checking cost estmates made after a regulation has been in effect (ex post estimates) against predictions of costs made before the fact (ex ante estimates). Such a comparison would probably be a useful and important element of a control system.

Comparability. Comparability of data and assumptions could be a serious problem, if OMB tries to set up a comprehensive system of oversight over individual regulatory proposals. A systematic method for comparing regulatory compliance costs of alternative policies could prove difficult and expensive, and the expected benefits might not justify the increased costs.

Ad hoc analysis of particularly burdensome regulations, or of clusters of regulations affecting a particular industry or process, might prove more effective.

Aggregation is another problem that could arise if one wishes to define and regulate an overall level of regulatory cost. It too could be avoided if one wishes only to correct ad hoc problems.

It may prove difficult to aggregate from individual regulatory compliance costs to estimates of regulatory burden in general. This is true partly because of the problems of cost estimation for individual regulations, but also because of the broader problems of joint costs and transfer payments whose benefits to other firms partially offset their costs to the regulated firms. If a central control system for aggregate regulatory costs is desired, therefore, it may have to be based more directly on indicators of aggregate activity--if such can be identified and validated--than on aggregation of cost estimates of individual regulations.

Costs of Analysis. Regulatory analysis itself, especially as a general system, imposes compliance costs--record keeping, data collection, analysis, negotiation among agencies and between agencies and industries, and opportunity costs of prolonged uncertainty about expected outcomes. Careful thought will be necessary as to how detailed an analysis is appropriate to various types of decisions, especially at the level of individual regulatory decisions.

In any event, the designers of the emerging central regulatory control system will soon need to choose which goals the system will pursue, so that effort can be targeted toward solving the problems associated with those goals.

Do Existing Methods Underestimate or Overestimate Compliance Costs?

Costs to Regulated Industry. Regulations not only impose immediate and measurable costs, but also deflect patterns of business decisionmaking. Such deflections are not necessarily costly, but they may be, and they are difficult to quantify and attribute to regulation amid the other forces in the business environment. Factors that would cause existing methods to underestimate costs of regulations to the regulated industry include these:

- Costs of bureaucratic overhead such as enlarged legal, research, and safety departments.
- Costs of lengthened decision processes and heightened uncertainty, in a climate of increased negotiation, potential litigation, and regulatory change.
- Costs of defensive planning, such as premature investments in control technology or other suboptimal investments to comply with regulatory deadlines.
- Costs of diversion of resources, both human and capital, from implementation to documentation, and from product innovation to control innovation.

- Costs of reduction in technological modernization when new plants must meet tighter standards than old ones.

- Costs of price inflation, as regulated firms bid up prices of control technologies.

On the other hand, engineering cost estimation methods and the self-interest of regulated firms will tend to exaggerate the costs that regulations impose. Reasons for overestimation include these:

- Some costs are joint costs of multiple regulations, or of regulations in general, only a fraction of which are due to any one regulation; they may be double counted in some estimates.

- Some costs are imposed not by a regulation itself but by the firms's choice of compliance strategy, which interacts with its pricing, marketing, and other corporate preferences. American auto firms, for instance, chose to invest in different control technology than Swedish firms. The resulting costs may be greater than should be attributed to the regulation per se.

- Ex ante cost estimates consistently overestimate compliance costs by ignoring future process changes and technological innovations. Ex ante estimates usually treat compliance costs as pure add-ons, such as end-of-pipe water treatment plants or stack gas scrubbers. (Some regulations, of course, require use of particular technologies, but many do not.) Once compliance begins, however, firms will usually adjust inputs and processes, and find other ways of reducing their costs. Moreover, a new regulatory constraint can sometimes stimulate a company to evaluate a whole production process, and lead to unforeseen net benefits. Other firms, if they know that regulation will require their competitors to clean up as well, will invest more heavily in control technology innovation and discover new methods of less costly and more efficient environmental control; recent examples include fluidized bed combustion, high-temperature incineration, and pulp and paper chemical recovery.

Costs to Society. Regulations also impose hidden costs on society as a whole, which are difficult to quantify and attribute, and extend beyond cost increases for regulated firms. Factors that lead to underestimation of costs by existing methods include these:

- Costs of overinvestment in control technology relative to its actual benefits, reflected in higher prices and higher interest rates due to diversion of capital investments, and in the opportunity costs of alternative uses of those resources.

- Costs of regulatory friction--such as paperwork, negotiation, uncertainty, and litigation--that exert a drag on a wide range of economic and social activities, especially on small business and entrepreneurial and innovative activities.

However, most estimates of regulatory costs greatly exaggerate their costs to society by focusing narrowly on costs to the regulated industry and extrapolating from these, ignoring offsetting benefits. Factors leading to overestimation of costs to society include these:

- Many costs to regulated firms--perhaps even most of them, in some cases--are simply transfer payments to other sectors of the economy, such as pollution control equipment manufacturers, not net costs in the economy; they may even be stimulating the growth of new and more productive sectors even as they hasten the decline of older and less productive ones.

- Many costs to regulated firms and their customers are also offset by gains to the economy from the costs thereby reduced to the victims of pollution and the taxpayers--costs such as health care, property damage and associated losses in property taxes, and lost productivity. That is, to the extent that environmental regulations are effective, their apparent costs may in fact represent merely correction of previous economic inefficiencies--externalities--rather than real new costs to the economy.

In conclusion, there is great disagreement among informed analysts on whether existing estimation methods overestimate or underestimate compliance costs to the regulated industry and to society. Many factors lead to overestimation or underestimation (listed above) and they are difficult to measure, pervasive, and hard to attribute explicitly to particular regulatory decisions.

It is possible that no satisfactory estimates can be developed for the overall costs of regulatory compliance, because they are beset by so many uncertainties. Yet, some costs can be estimated, and some uncertainties can be reduced, and therefore some regulatory decisions can be improved through judicious analysis and control.

Can the Aggregate Costs of Government Regulation Be Managed through a Regulatory Budget?

Regulatory reform advocates have suggested a "regulatory budget" by which OMB could set annual limits (as it does with the fiscal budget) on the amount of costs each regulatory agency would be allowed to impose by its regulations. Proponents of such a system argue that (1) Federal regulatory activities do impose aggregate costs which should be controlled, (2) as with fiscal budgeting, an overall constraint would force the agencies to set priorities and increase the cost-effectiveness of the regulations they impose, (3) regulations may also impose differential hardships on particular industries or regions, which deserve the attention of a central control system, and (4) a regulatory budgeting approach might require less detailed analysis and intervention by a central control system than would the case-by-case oversight of individual regulations.

As a practical matter, however, neither the concept of a regulatory budget nor measurable indicators of it have yet been demonstrated and validated.

It is not clear how many of Government's regulatory functions would be encompassed by the proposed regulatory budget, but each of the possible answers poses problems. Government regulatory activities are so pervasively intertwined with society's system of rights and exchanges, that it would be hard to isolate and establish individual costs for them.

Another problem is that although the analogy of a "regulatory budget" to the Federal fiscal budget might be attractive to some advocates of the plan, it does not seem valid. One major difference is the absence in the regulatory budget of any means of positive verification of expenditures: as one discussant put it, there are no canceled checks at the end of the year to facilitate an audit. Further, while fiscal costs are incurred solely by Government action, regulatory costs are incurred by nongovernment parties alleging that they are required by Government. Since the nongovernment actors control the response, and thus to a significant degree its costliness, the cost data are beyond clear Government control, and are subject to strategic behavior and exaggerated claims by parties wishing to minimize or thwart Government action. In short, a fiscal budget has a single client and tangible, auditable flows of money; a regulatory budget has neither.

Setting the level of a budget for annual environmental regulation costs would be a legislative function, just as fiscal budget levels are set by Congressional appropriations. Even here the fiscal analogy must be used cautiously, however, for even if Congress did set regulatory budget levels they might be invalidated where they conflicted with statutory requirements.

One purpose that has been advanced is that a regulatory budget would enhance overall economic efficiency. It is not clear that regulatory budgeting would necessarily produce greater efficiency even if it were fully established. Fiscal budgeting is heavily influenced by political factors within the agencies and in the Congress, and this could happen with regulatory budgeting as well; besides, any new documentation system compounds the administrative inefficiencies of documentation and justification as well.

Furthermore, if the regulations affect only the profitability of the regulated industry, and not the efficiency of the economy as a whole, then one has only a special pleading rather than a general justification for regulatory budgeting.

If one seeks to develop the regulatory budget by aggregating information about individual regulations, one must deal with all the problems of micro-level cost/benefit analysis, such as attribution of joint costs, transfer payments, unreliability of data, difficulty of establishing baselines, and problems associated with aggregation itself.

Some analysts have suggested that regulatory budgeting might be effective by forcing an annual regulatory review process, even if it proved intractable as a substantive analytical or control procedure. This could be true, but it would not be a regulatory budget in any conventional meaning of a budget;

it would be simply an administrative arrangement in which regulatory decisionmaking authority was somehow shared bettween each operating agency and OMB. Such an arrangement would be justified only if it were kept politically accountable within the intent of the agencies' statutory mandates, and if it provided benefits greater than the increased transaction costs associated with negotiation and shared authority.

It is not clear, as a practical matter, that the overall level of regulatory compliance costs is really the issue that concerns most of the American public or even the regulated industries themselves. The overall level is a useful symbol for organizing diverse constituencies to press for regulatory reform, but specific regulations really motivate each constituency. For some constituencies, such as primary extraction and processing industries, it is pollution control and occupational safety rules; for others, such as the construction and fabrication industries, it is perhaps occupational safety and labor and affirmative action regulations; for universities, it is affirmative action, women's athletics, barrier-free access, and faculty time accounting requirements (the latter imposed by OMB itself). Most constituencies probably gain from and approve of many regulations even though they feel burdened by others. Perhaps the only issues on which all agree are the desire to slow the rate of regulatory change, and to eliminate, on an ad hoc basis, regulatory inconsistencies, redundancies, and absurdities.

OMB control of the overall level of regulation will not provide direct solutions to these more specific complaints, and indeed it might simply divert effort away from them toward the creation of a new budgeting system. This would be unfortunate.

What Lessons Does This Discussion Offer for the Design of a Central Control System?

Everyone agrees that some environmental regulations are poorly designed and could benefit from cost-reducing changes. It is less generally agreed what changes in which regulations would be desired, and not at all agreed that the overall level of regulation is an important problem. Most of the discussants were sympathetic to the need to ameliorate some of the compliance costs imposed by environmental regulations, but they remain quite skeptical of current proposals for comprehensive central regulatory control systems. This skepticism applies to "cookbooks," or detailed procedures for comparative cost/benefit analysis of individual regulations, and to the notion of a regulatory budget.

OMB seems to feel that the mandate to implement such a system is now a given, and that it must therefore get started on something, and in some direction, though it does not yet have a clear rationale for what exactly is required. Ironically, in this mandate OMB is itself becoming a regulatory agency, regulating the other regulators; and in its impulse to do something without knowing quite what, it is flirting with exactly the mentality of a new regulatory agency that has created many of our current problems of regulatory compliance costs. It behooves OMB, therefore, to move cautiously in developing case-by-case understanding of the problems, analytical procedures and methods, and possible solutions before mandating a new full-blown system, lest it simply reinvent existing problems at a higher level of review.

Past experience suggests that while good analyses can improve Government decisions, most new analytical systems that have been mandated have failed to achieve their intended purposes; and in the process they have added new layers of bureaucracy, paperwork, and administrative inefficiency. Benefit/cost analysis of water projects, for example, has given birth to a sizable economic literature and has undoubtedly stopped the construction of some egregiously poor projects, but the bulk of the water development continues, with the simple addition of new layers of paperwork justifications.

The same is true of Management By Objectives (MBO) in the 1970s, and of attempts to create comprehensive information systems generally, most of which have failed and wasted resources. Probably the only new major Government-wide analytical system that has stabilized and survived is the preparation of environmental impact statements (EISs), and this one has survived not because it produces good analysis (though it sometimes does, it often does not), but because it opens new avenues for influence on decisions by affected parties, through public involvement procedures and judicial review.

On the other hand, good analyses of particular proposals can often help to stop egregiously bad proposals and to encourage unusually promising ones.

OMB does have at least three promising roles open to it in regulatory reform, roles which it has played in the past and which could aid substantially in current regulatory issues. First, it can serve as an advocate for efficiency, by working to improve both the administrative efficiency of U.S. Government operations, and the social efficiency of its programs. This role is strongly consistent with the professional ideals of OMB staff, although it is not always consistent with the Agency's practical political reality as confidential staff to the President. Much could be done to improve regulation if OMB were simply to work case by case with the agencies in adjusting the most egregiously inefficient regulations, without any overall paperwork systems.

Second, OMB can serve as the "necessary enemy" of the agencies, challenging proposals or programs based on established assumptions, methods, and priorities that may have outlived their validity. By doing so it aids innovators within the agencies in achieving better results. All human organizations gradually fall into stable patterns, and most require external challenges to stimulate re-examination of such patterns; OMB is institutionally well placed to raise such questions about regulations, as it does already about expenditures, if it can develop sufficient analytical competence and avoid spreading its effort too thinly.

Third, OMB can serve as an advocate for methodological improvement, both within and beyond Government, as it has done frequently in the past in such areas as program budgeting and benefit/cost analysis. The mandatory systems associated with these labels have not been especially effective, but the analytical methods have improved, thanks in part to OMB's encouragement.

The following suggestions may help OMB meet its responsibility under Executive Order 12291, while clearly recognizing the difficulties and complexities raised in the workshop:

1. Start by discriminating among different types of regulations and their associated cost patterns--such as procedural and reporting requirements vs. mandatory technologies vs. performance standards--in order to select priorities for special analyses.

2. Start with solid cases and build outward gradually toward the harder ones: build a control system incrementally from real pieces, not overnight from an untested concept. OMB can usefully work in the direction of a central control system without necessarily expecting to arrive at a full-blown regulatory budget; and if in the process it can help weed out a few of the most inconsistent, incomprehensible, ineffective, or inefficient requirements, it may achieve all that should be expected.

3. Recognize and encourage the clash of adversary analyses: The results will be far more useful than any officially sanctioned "cookbook." This requires also a willingness to keep the analytical process visibly accessible to the interested public, a role somewhat less comfortable to OMB but one which has a high payoff in legitimizing the results.

4. In analyzing proposals either for new regulations or for changes in existing ones, focus analytical efforts on the differences among alternatives, including always the option of no change from the regulatory status quo. Sophisticated cost estimation for a single proposal is of little use for decisions without equally sophisticated analysis of its benefits and comparison of these with the costs and benefits of alternative means to the same end, and industrial compliance costs alone are not an adequate or legitimate basis for public regulatory decisions. The Council on Environmental Quality regulations for implementing the procedural provisions of the National Environmental Policy Act, and the EIS methodological literature, provide useful discussion of some of these analytical issues.

5. Encourage scholarly thought and experimentation on broader or longer term questions, such as the relative merits of national minimum standards vs. regionally differentiated standards, regulatory budget proposals, and other new alternatives to burdensome forms of regulation.

II. LIST OF WORKSHOP PARTICIPANTS

NSF WORKSHOP ON EFFECTS OF ENVIRONMENTAL REGULATION ON INDUSTRIAL COMPLIANCE COSTS AND TECHNOLOGICAL INNOVATION

September 10-11, 1981

Category	Name	Affiliation
Authors	Christopher T. Hill	MIT Center for Policy Alternatives
	Raymond J. Kopp	Resources for the Future
	Paul R. Portney	Resources for the Future
	Victoria M. Potter	Consultant
	Joseph A. Vasquez, Jr.	ICF, Inc.
	David E. Wojick	Adams & Wojick Associates
Reviewers	Richard N.L. Andrews	University of North Carolina
	Robert W. Crandall	Brookings Institution
	Leslie Dach	National Audubon Society
	George C. Eads	Rand Corporation
	Khristine Hall	Environmental Defense Fund
	Robert M. Heine	Conoco Inc.
	Joe N. Nay	Performance Development Institute
	Carl W. Noller	U.S. Chamber of Commerce
	Robert Percival	Environmental Defense Fund
	Michael A. Pierle	Monsanto Company
	Larry E. Ruff	Synthetic Fuels Corporation
Others	Warren Easley	Monsanto Company
	James C. Hersey	Kappa Systems, Inc.
	Van E. Langley	Conoco Inc.
	Jeffrey A. Kolb	Environmental Protection Agency
	Richard A. Tropp	Environmental Protection Agency
	Gail Updegraff	Department of Agriculture
	Jonathan B. Weiss	Department of Transportation
	Barbara A. Chow	Office of Management and Budget
	Edward H. Clarke	
	Art Fraas	
	Brian Mannix	
	Mahesh K. Podar	
	Jim J. Tozzi	
	John Marcum	Office of Science & Technology Policy
	Denis Prager	
	Harvey Averch	National Science Foundation
	Alden S. Bean	
	Geoffrey M. Holdridge	
	Frank L. Huband	
	Leonard L. Lederman	
	Richard E. Morrison	
	Trudy L. Solomon	
	Robert R. Trumble	

III. SELECTED QUOTATIONS FROM THE WORKSHOP PROCEEDINGS

NOTE: This selection of quotes from the workshop proceedings gives a flavor of some of the main issues, participants, and subjects discussed during the workshop.

The purpose of the workshop is to bring together individuals with diverse viewpoints and experiences, hoping that the ensuing discussion will both illuminate the areas of general agreement and sharpen our understanding of the areas of disagreement. (Huband)

What I see evolving is a central control system on regulations, [which] is being debated in this town. I think it will continue to be debated over a number of years....

Assuming that we are going to have a control system, we would like to see, as a result of these and other papers, some idea of how and what is the current status and what can be done under current methodologies to provide a basis for assessing the impacts of regulation. (Tozzi)

The main objective of my paper is to address the contribution of technological innovation and learning to regulatory compliance cost. A secondary objective is to look at what our understanding of innovation and learning might contribute to understanding how better to regulate, assuming that in the real world in which we live we will continue to regulate in some way....

There has been a presumption in most of the literature that regulatory cost analysis is pretty straightforward. It might be tedious, it might be expensive, but it's pretty straightforward. We know how to do it. And the real challenge is on the benefit side. Most of the literature has had to do with how the scientific problems are so terribly complicated on the benefit side. I believe that if we look at the cost side, we will find that there are problems on that side as well.

I would not recommend that we continue to use engineering cost estimation until NSF has funded a 5-year program to improve methodology. That wouldn't help OMB or the world in the short term. (Hill)

We begin our paper by asking, why in the world do you want to estimate the cost of complying with Federal regulations anyway? And we discuss what we see as the most important reasons:

(1) Estimates of the cost of particular regulations are a precondition if we're going to do any kind of benefit/ cost analysis, cost-effectiveness analysis, or regulatory impact analysis, if that's going to be required as it is in Executive Order 12291. So, if you're going to do that kind of analysis of regulations, obviously you're going to need some estimate of the costs that go along with the regulation.

(2) The second reason has to do with their use in the past and their prospective use in the future as inputs to macro studies of the impacts of regulations.

(3) The third reason we need to know something about the cost of complying with Federal regulations is that they're essential if we're going to make some regulatory budget approach actually work--something about which I am skeptical....

There seems to be a lot of enthusiasm about pursuing the idea further. If we even want to pursue the idea further, we're going to need estimates of the cost of compliance....

Most of the surveys have to do with ex post costs. In other words, after the fact, how much did you spend last year or 2 or 3 years ago on environmental regulations. If we want to do benefit/cost analysis of prospective regulations, or to examine the distributional or macroeconomic effects of potential regulations, then we need ex ante estimates, or estimates of the costs of proposed regulations before the fact. (Portney)

What is the thesis of our paper? Why did we choose process models and econometric models as vehicles for future compliance cost estimation?... We were looking for structures. We reviewed what had been done in the past on compliance costs. It was a hodgepodge, a bag of various different types of methodologies which were really going to be tailored for individual kinds of regulations. But we were looking for a structure, some way to organize compliance cost estimation around a basic structure. (Kopp)

I have spent most of my time looking at the benefit side, but what strikes me here is the same thing that struck me there, how little empirical, numerical data there are to support any exact numerical estimate of costs or benefits. And I think that's the important message to come out of these papers, because at the same time there is a lot of effort politically in regulatory reform legislation to require some sort of detailed cost/benefit analysis....

It's incumbent on people who spend their research time in this area to point out to a lot of the politicians who are grasping at what is apparently a very rational approach, that we really don't have the methodological experience to implement it in an appropriate fashion. That message doesn't seem to be getting across. (Dach)

The paper I developed was designed primarily to provide some information based on a case study, in order to evaluate some of the issues raised by the other authors....I examined the emissions control regulations that were promulgated over the last 10 years, [which] regulate emissions from automobiles....We tried to look at the effect of Federal emissions control regulations on technical innovation in the automobile industry....

We used a proxy for technological innovation, which was manufacturers' investment in research and development for emissions control devices. I do recognize that there may be some people who will argue that that's not an appropriate proxy, but at least I assumed it was a good start. (Vasquez)

I want to remind the group that regulation can inhibit innovation. There is an undercurrent here that OMB should tell EPA and DOT how to do cost analysis so it will all be consistent, and so the mythical decisionmaker will have a uniform basis on which to decide.

But this control mechanism is a new kind of Government regulation, and we don't know how to do the analysis. And it's clear that if a cost analysis regulation were established today prescribing how these studies ought to be done, it would be modeled after engineering cost estimation. We know that for lots of reasons...engineering cost estimation isn't the right way to go. It's not the only wrong way, but it isn't the right way, and we need room for experimentation and learning on how to do these things. (Hill)

One key point is that there does seem to be a great variation among cost estimation methods in common use.

The question is, can some of these be ruled out in favor of a small number of better ones? Can and should OMB sponsor any single method or cookbook, in order to achieve some kind of consistency and comparability?...Or would the cure...in some cases at least be worse than the disease? (Andrews)

There is confusion in writing a 3,000-page document, with an enormous number of references. There is an enormous cost there. You all see it when a new, big regulation comes out; millions of dollars are spent just by people trying to figure out what it means....

Why do people want less regulation? I don't think its a perception that their ox is being gored; it's a general perception that regulations are costing too much. Most people couldn't name a regulation if you asked them to....But "intrusion" is the word. People have just become aware of the fact that they're being boxed in by government rules....People have become aware of an enormous increase in Federal power, not through spending, and not through actions of agencies, but through regulating people. (Wojick)

I have heard two theories of why we should have a regulatory budget, and what it should focus on:

(1) We want to aggregate regulatory costs because the total demands imposed by Government on the economy, not only the tax burden but the burden of regulations, are getting very large and worrisome in the aggregate. And we ought to have an idea of what that burden is.

(2) The other theory is that we should look at individual sectors that are being hit with a particularly worrisome burden. The one that comes to mind is the automobile industry, where capital expenditures are a problem. The electronic utilities are another case. (Mannix)

I don't think you necessarily would get more efficiency with a regulatory budget. But the proponents would say, look, if you gave them a budget so that they couldn't regulate till the cows came home, in other words if you constrained their appetites somehow, that they'd pick only the very best regulations. (Portney)

So far we've been talking about whether or not we should do regulatory budgets. Assuming for a moment that we are required by the Congress to do regulatory budgets, I'm not sure we can do a regulatory budget right now. (Podar)

If you don't ask the right questions to start with, you're going to have a total which is very misleading. I would insist that if you're going to do that, you should at a minimum address the indirect costs and the benefits of regulations. [If this is impossible,] then my argument would be, don't do it. (Hill)

I would suggest that if we really want to get some action with respect to a regulatory cost accounting program or budget, then we need a directive from OMB that says something like, "We would like you to start moving toward regulatory cost accounting programs." This would force us to work more seriously trying to figure out which costs are going to be included, and which estimation methods to use. (Updegraff)

It seems to me that what industry is looking for is better efficiency through lack of duplication. The agencies can each go their own way in regulation, and there is now no general management control in that process....

You must get going....If we agree, as the public tells us, that we are overregulating, then there has to be a start somewhere. Somebody has to take leadership and...take that first step. (Pierle)

I think it's inevitable that something will be done to establish control over regulatory costs. I would hope to see, as much as possible, an equivalent concern for the methods and mechanisms for addressing the benefits of regulation, and for what those mean for the policy decisions, and an equivalent concern for the total impact on specific sectors on the benefits side. (Hill)

I think this has been a useful exercise. We all realize how much we don't know yet, and therefore how much is left to be learned. (Morrison)

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THE EFFECTS OF TECHNOLOGICAL INNOVATION AND REGULATORY DESIGN ON REGULATORY COMPLIANCE COSTS

by

Christopher T. Hill
Center for Policy Alternatives
Massachusetts Institute of Technology
Cambridge, Mass.

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1.0 Introduction

1.1 Background

The last 6 years have witnessed an explosive growth in the demand for economic analysis of Government regulatory programs. While economic analysis has been applied in a variety of regulatory contexts, its most controversial use has been in the area of the regulation of environmental, safety, and health hazards. As the costs of the environmental, health and safety laws adopted or strengthened in the 1960s and early 1970s have become more apparent, more and more attention has been focused on the costs they impose on industry and on the public.

Within the Federal Government the formal requirements for economic analysis of regulation have had two origins. First, several of the environmental statutes, including parts of the Clean Air Act, the Federal Water Pollution Control Act, and the Toxic Substances Control Act, require that agencies consider the economic implications of a regulation as part of the standard-setting process. Second, for those agencies and regulatory regimes that do not require economic analysis as part of the decision process, a series of Presidential executive orders has established ever more rigorous requirements for regulatory analysis. Under President Ford, Executive Order 11821 established a requirement that agencies consider the "inflationary impact" of proposed regulatory decisions. Later, President Carter in Executive Order 12044 extended and expanded this requirement to require a draft regulatory analysis of all significant regulations. Most recently, under Executive Order 12291, promulgated on February 17, 1981, President Reagan has required that where possible under the law all significant new regulations must meet a cost/benefit test.

As the requirements for economic analysis of regulations have become more stringent and quantitative, and as the policy decisions of regulators have been made more dependent on the outcomes of economic analysis, the need has emerged to improve the quality of regulatory analysis to be sure that it is done both fairly and accurately. Clearly, a regulatory cost analysis intended to support a discussion of the inflationary impact of a proposed regulation does not need to be as accurate as one intended to support a judgment of the amount by which the marginal benefits of a proposed regulation exceed its marginal costs. In this context, of course, accuracy refers not only to numerical soundness but to conceptual and methodological soundness as well.

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Most regulatory analyses of proposed environmental regulations have stressed the cost side of the cost/benefit evaluation. On the other hand, the focus of the theoretical and conceptual literature on environmental cost/benefit analysis has been on methodologies for analyzing the benefits of regulation and on the policy implications of the use of cost/benefit analysis in decisionmaking. The tacit assumption is that cost analysis per se is reasonably well in hand. However, this paper will argue that most regulatory cost analyses are based on complex but naive static models of the responses of firms to changes in their environments, that were not intended for this purpose and are the cause of significant error. It finds that the analysis of the cost of regulation is in considerable disarray and that the methodologies must be improved if such analyses are to be reliable and credible.

1.2 Purpose, Approach, and Scope

The purposes of this paper are to describe and assess the current practice of regulatory cost analysis, to show how current practice systematically overstates regulatory costs, and to identify opportunities to improve that practice. It focuses on the contributions of technological innovation and change to reducing the costs borne by regulated industries. A second purpose is to describe how the detailed design of command and control and economic incentive regulatory programs can influence corporate technological responses and thus the costs ultimately paid by industry and the public.

This paper is focused on the prospective analysis of proposed regulations, rather than on the retrospective analysis of regulations that have already been put into effect. Such prospective, or ex ante, analysis is the problem faced by a regulatory analyst in an agency today. As compared with ex post evaluation, in ex ante analysis there is greater uncertainty about the responses of industry, both in terms of compliance and in terms of technological innovation and change, as well as greater uncertainty about the costs that will ultimately be paid.

A review and analysis of research and information from existing sources is the basis for this paper. It draws on academic literature, earlier studies funded by Federal regulatory agencies, and the general literature on technological innovation and learning. A number of its assertions are based on more general arguments about innovative behavior. Clearly, there is need for additional modeling, for empirical studies of existing regulations, and for experiments in regulatory program design to improve our understanding of the regulatory process and the associated industrial response.

This paper is concerned primarily with command and control regulations of the type adopted in the United States since around 1965. It is concerned with regulation of the processes firms use rather than of the products they make. In particular, it focuses on requirements typified by those under the Clean Air Act, the Clear Water Act, and the Resource Conservation and Recovery Act. It does not address product regulations imposed by the Food, Drug, and Cosmetic Act, the Toxic Substances Control Act,* or the Consumer

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* TSCA gives EPA authority to regulate industrial processes and practices, although the actions taken to date under TSCA have not been of this type.

Product Safety Act; nor is it concerned with regulations under the Occupational Safety and Health Act, although much of the analytic content applies to them.

We are concerned here only with methods for analyzing the costs of regulatory programs. The analysis of the benefits of environmental regulation has been addressed in a number of other studies and reports. For recent reviews, the reader is referred to works by Freeman (1979), Ashford, Hill, et al. (1980), and CPA (1981), who report on the conceptual difficulties, complexities, and uncertainties of the benefits side of a regulatory analysis. Benefits analyses pose challenges that are at least as great as any faced by a cost-side analyst, and when chronic health hazards are of concern, the challenges are much greater. While we focus here on the cost side, we must keep in mind the importance of improving methods of benefits analysis.

This paper also does not consider the appropriateness, problems, or costs to society of using the cost/benefit approach for making public choice. Kelman (1981) points out that the cost/benefit analysis approach reflects a utilitarian view of social choice that is no longer in favor with moral philosophers, and that it threatens, through monetization of certain nonmarket values, the foundations of social behavior. Similarly, Schultz and Kneese (1981) show how cost/benefit analysis addresses only a special case of utilitarianism and does not address other legitimate concerns of society, such as protection of individual rights. On a more instrumental level, use of cost/benefit analysis may replicate in the public sector the problems that narrow financial analysis brings to private firms, a subject I have recently explored elsewhere. (Hill, 1981) Thus, while this paper recognizes the current role and importance of cost/benefit analysis in regulatory decision-making, this should not be taken as agreement that cost/benefit analysis is the preferred method for analyzing public choices.

The first goal of any environmental regulatory program is to achieve a reduction in the risks to human life, health and the natural environment posed by environmental hazards. However, there are many ways to achieve this social goal, and each may impose different costs on industry and on the public and may create different problems for regulatory cost analysis. There is no social advantage in requiring industry to spend more than necessary to comply with a socially imposed regulatory requirement, and it is in everyone's interest to seek low-cost ways to achieve a regulatory goal consonant with achieving other social goals such as procedural fairness, equity, and security. Section 6 of this paper examines the consequences for innovation and for regulatory costs of the detailed design of both command and control regulations and some of the more popular alternatives for social control of risks, especially economic incentive approaches.

1.3 Organization of This Paper

Sections 2 and 3 of this paper address the static and dynamic modes of analysis of the costs imposed on individual firms by proposed environmental regulatory requirements. The static mode, addressed in section 2, is concerned with how cost engineers and financial analysts ordinarily look at the costs of compliance and at the other costs imposed on the firm by regulation.

Section 3 examines the dynamic mode of analysis of costs at the firm level, including technological innovation, learning, and the effects of changes in the demand for inputs. Section 4 is concerned with aggregating firm-level costs to an entire industry affected by regulation. Section 5 addresses how interactions among regulatory programs complicate regulatory cost analysis and mentions briefly the relationships between private, firm-level costs and total social costs. Section 6 addresses the effects of regulatory design on compliance costs for command and control and economic incentive regulations. Section 7 presents some findings and conclusions about the process of regulatory cost analysis under the current circumstances and highlights research opportunities for improving it.

2.0 The Static Analysis of Firm-Level Costs

Projecting the costs of a proposed regulation at the firm level is usually approached using the standard methods of engineering cost analysis. One estimates the direct private costs faced by a firm for compliance and other purposes. Direct private costs are costs that affect the profit and loss statement of the regulated company. Since they are based on detailed descriptions and disaggregations of a process flow sheet, such engineering cost estimates are often highly detailed, and are often wrong, especially because they are unable to consider the potential contributions of the new control technology and new process technology, which is so often at the heart of the responses of industry to regulation. To provide a basis for understanding the impact of new technology in regulatory analysis, this section examines the engineering cost analysis tradition in some detail. Section 3 then examines technological innovation and dynamic analysis of firm-level costs.

2.1 Engineering Cost Analysis for Compliance Costs

The well-established tradition of engineering cost analysis for financial decisionmaking by private firms has been adopted essentially without change for regulatory cost analysis. Broadly speaking, two functions are involved: engineering cost estimation, which entails estimating the fixed and variable costs associated with purchase and operation of specific items of plant and equipment, and engineering economics, which entails analyzing the implications for the firm of an investment choice from among the alternative items of plant and equipment whose costs have been estimated.

Engineering economics, also known as managerial economics, engineering economy, and project financial analysis, is a well-developed field, as attested by the existence of many standardized texts. See, for example, Grant, Ierson, and Leavenworth (1976); Riggs (1977); Taylor (1980); White, Agee, and Case (1977); DeGarmo, Canada, and Sullivan (1979); and Peters and Timmerhaus (1980). For the most part, these texts are concerned with the tools used to assess the implications of a particular schedule of costs for the firm. They examine at great length the implications of that cost schedule, and of such matters as taxes, the financial structure of the firm, depreciation rules, and equipment life for the firm's cash flow and profit and loss statement. Except for brief chapters on public investments, these texts assume that (1) the decisionmaking unit is a private firm, (2) the firm is a profit maximizer, or tries to accomplish its objectives at the least cost, (3) the firm knows its future cost and income streams with certainty or can attach specifiable probability distributions to those streams, and (4) the firm does not consider the external costs of its actions when making decisions.

The cost inputs to the engineering economic analysis are provided by the cost engineer or the engineering cost estimator. Standard references in this field are texts by Ostwald (1974), Park (1973), and Weaver, Bauman, and Heneghan (1963). Helpful recent papers on cost estimation for process equipment have been published by Cran (1981) and Desai (1981). Standard approaches to cost estimation have been elaborated in some detail for pollution control devices in general by Uhl (1979) and for air pollution control devices installed pursuant to the New Source Performance Standards provisions of the Clean Air Act by PEDCo Environmental, Inc. (1979). Vatavuk and Neveril (1980) have published a series of papers on cost estimation for air pollution control devices.

Using a variety of techniques developed over the years, the cost estimator makes estimates of the capital and operating costs arising from the adoption of specified items of equipment, either for ordinary production or for compliance with regulatory requirements.* Cost estimation is relatively straightforward for so-called "end-of-pipe" approaches to compliance, because they involve attaching a separate piece of equipment of established design to a production facility to recover its effluents or render them unobjectionable under the law. In general, cost estimation is more difficult when regulations are met through process modifications because such modifications are not known in advance, and because allocation of joint costs and benefits to production and environmental control becomes an issue.**

It is customary in cost estimation for regulatory compliance to use a "model plant" approach, in which one estimates the incremental costs of compliance for hypothetical plants that typify those expected to be built, or that exist in the industry in question. These hypothetical plants do not take into account any special costs or opportunities associated with local conditions. It is also customary to treat income from the recovery of byproducts and cost reductions from improvements in the productivities of labor or resource inputs as offsets to compliance costs rather than as benefits of the regulation.

Cost estimation has taken on a specific format closely allied with the economic and accounting principles of business firms. These principles are appropriate for analyzing costs of compliance for a particular firm, but they can not address such matters as the contributions of firms outside the industry, technological change, and the difficult-to-predict dynamic variables that influence industry-wide compliance costs in the long run. It is important to recognize that regulatory cost analysis is not being carried out for an individual firm that will have to decide how to comply, but rather by society, which is trying to decide whether and how to change the behavior of all firms in the industry to attain the most effective and equitable allocation of the Nation's resources overall.

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* Typically, design and cost estimation are separate functions, which inhibits feedback from cost implications to design changes.

** This paper does not address the question of creating incentives for accurate cost estimation. See White (1981).

The following subsections briefly describe the process of engineering cost estimation in order to provide a basis for discussing some of its limitations and inherent biases when used in regulatory analysis. For more specific procedures and input data, the reader is referred to the texts, articles, and reports mentioned above. For example, Peters and Timmerhaus (1980) offer an extensive bibliography of practical articles on cost estimation.

2.1.1 Capital Cost Estimates

It is customary to make cost estimates for engineering projects at five levels, each level representing a higher accuracy and a more firm commitment to action by the decisionmaker. Table 1, from Uhl (1979), shows the expected accuracy for and the appropriate decisions to be based on the five levels of estimates. It should be emphasized that the accuracy estimates apply for "well-established" technologies and that ranges may be wider for newer technologies. Table 1 also summarizes the kinds of information needed to perform cost estimates at each of the five levels.

The resources required to perform cost analyses at the more accurate levels grow rapidly. Table 2 shows estimates of the costs of performing cost estimates at various levels for single process plants in 1979. These are rough estimates that are based on an original source dating from 1964, so they must be viewed with caution. They apply to well-known technologies, and the costs of estimating costs would be higher for new technologies. Furthermore, compliance cost analysis for an industry of several plants would cost more, since several model plants must be described and cost estimates tailored for each one. Thus, these data highlight the fact that making credible cost estimates can cost a substantial amount of money.

Regulatory cost analysis is nearly always based on "study" estimates. The next more accurate level, the "preliminary" estimate, requires specification of site-related information that the model plant approach, based on hypothetical typical plants abstracted from local conditions, can not accommodate. For purposes of estimating costs for the "Background Information Document" for a New Source Performance Standard under the Clean Air Act, PEDCo (1979) states that a "study" estimate is adequate. The implications of this practice are that, first, such an estimate will typically cost $10,000 to $25,000 to make for one well-known end-of-the-pipe control technology, and second, a cost/benefit ratio based on such a calculation can never be more accurate than that, with a bias toward overstatement.

TABLE 1. DEFINITION OF FIVE BASIC TYPES OF ESTIMATES OF TOTAL PLANT COST

Type[a] (Each has several designations)	Characteristics	Purpose	Usual Reliability[b]
1. Order-of-magnitude[c] Ratio	Rapid. Very rough.	Preliminary indication. Check on result by more detailed method.	About + 30% - 60%
2. Study[c] (commonly a so-called factored estimate)	Requires flow diagram, material and energy balance, type and size equipment.	For generalized evaluations. Guidance for further investigation. Basis for process selection. R&D guidance.	± 30%
3. Preliminary[c] Budget Authorization	In addition to above, surveys and some engineering of foundations, transportation facilities, buildings, structures, lighting, etc.	Basis for decision to undertake detailed engineering. Sometimes basis for budget authorization. Can be for generalized evaluation, but usually for site-specific installation.	± 20%
4. Definitive Project Control	More detailed engineering, but usually short of complete specifications and working drawings. Requires experienced estimating organization and substantial outlay.	Sometimes the basis for budget authorization. Provides improved estimate of project to be built. For site-specific installations.	± 10%
5. Detailed Firm Contractor's	Complete site surveys, specifications, working drawings.	Made to control cost of project being built. For site-specific installations.	± 5%

[a] This is a representative and comprehensive list of the types of estimates for total plant cost. Other such lists differ in the number of estimate types and their descriptions.

[b] These apply for well established technologies. For newer technologies, the ranges may be wider, particularly for the first three types of estimates.

[c] The first three types of estimates are also termed "conceptual estimates."

Source: Uhl (1979)

TABLE 2. TYPICAL COST RANGES
FOR PRODUCING CAPITAL COST ESTIMATES[a]

Type of Estimate	Total Plant Cost		
	Less than $2 million	$2 million to $10 million	10 million to $100 million
Order-of-Magnitude	$ 2,000 - 10,000	$ 5,000 - 20,000	$ 8,000 - 25,000
Study	$ 4,000 - 12,000	$10,000 - 24,000	$16,000 - 32,000
Preliminary	$12,000 - 30,000	$24,000 - 50,000	$40,000 - 80,000
Definitive	$20,000 - 50,000	$ 50,000 - 100,000	$ 90,000 - 200,000

[a] The figures are intended only as a rough guide. The range of activities covered by these costs can be considerable; depending on the type of estimate, it can include engineering, drafting, surveys, travel, copying, communication, office overhead, besides the actual cost analysis.

Source: Uhl (1979)

To make a detailed equipment cost estimates it is convenient to divide the expenditures for capital equipment into three broad groups:

> "Group I includes items with standard designs and sizes, such as pumps, tanks, fans, and some air pollution control devices. Group II includes partially standardized equipment, such as heat, exchangers, clarifiers, and fabric filters. Group III consists of equipment with special design or size requirements, such as distillation columns, pressure vessels, reactors, and pollution control equipment for large systems.
>
> Price lists for Group I equipment are available from fabricators or vendors, and Group II equipment costs can usually be calculated by a correlation analysis. No standard price lists, however, are available for Group III equipment; after preliminary process criteria are established, price estimates should be secured from several sources." (PEDCo., 1979, p. 40)

The uncertainties in component costs can be expected to be greatest for Group III and smallest for Group I. Unfortunately, for any regulation that requires significant control expenditures, Group III costs are likely to dominate the total costs, and thus, the uncertainties. Furthermore, Group III costs are the most sensitive to the local conditions that are omitted from the "study" estimates used in regulatory analysis. As a consequence, capital equipment cost estimates for environmental controls are likely to be highly uncertain, even for end-of-pipe devices of known design.

The capital investment cost of a new project in industry involves not only expenditures for equipment but also a wide range of auxiliary capitalized expenditures for such things as installation costs, services and utilities, and site improvements. In addition, capital costs are conventionally defined to include property taxes and insurance. In the engineering cost analysis approach, rules of thumb have been developed for assigning these auxiliary investment costs to a project. Many articles featuring different allocation rules have been published. In a recent article, Cran (1981) reported that a factor of 3.2 plus or minus 0.86 could satisfactorily represent the ratio of "battery limits" costs* to equipment costs for a wide range of process plants. For the most part, such rules of thumb are based on extensive industrial plant construction experience but not on experience with environmental control systems. Retrofitting end-of-pipe treatment methods is likely to be more disruptive and constrained by existing facilities and thus more expensive than new construction. On the other hand, site preparation and costs for providing utility connections are likely to be lower for add-ons. No information has been found on how these rules of thumb might differ from the norm for environmental control projects.

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* "Battery limits" is a geographic boundary defining the coverage of a specific plant, including all process equipment but excluding storage, utilities, administrative buildings, auxiliary facilities, and site preparation.

2.1.2 Operating Cost Estimates

Operating costs include labor, raw materials, energy, maintenance, and other recurring costs of operation of industrial facilities. In the engineering cost analysis approach, once the items of equipment and their sizes and operating characteristics have been specified, it is relatively straightforward to estimate the amounts of raw materials, energy and labor required to operate the facility in its early years. One must, of course, remain cognizant of the uncertainties in the future prices of such inputs over the lifetime of the project. Furthermore, operating inputs may decline substantially over time due to "learning," as discussed in Section 3.

Labor costs include both hourly and supervisory costs. Hourly labor requirements are generally specified based on the vendors' estimates of labor requirements, and supervisory labor is based on the application of a rule-of-thumb ratio such as 15% of supervision to direct labor. In this case also, it is not known whether environmental control devices require more or less supervision per unit of hourly labor than do production processes. There is some reason to think that the supervisory attention may be greater for environmental control systems, in view of the higher level in the firm at which environmental control decisions are generally made. (Ashford, Heaton and Priest, 1979)

2.1.3 Total Annualized Costs

The annualized cost of compliance consists of the sum of the annual operating costs and the annualized costs of owning capital plant and equipment. The translation of capital investment costs into annual costs of ownership is not straightforward or uniquely defined and is a major concern of the field of engineering economics discussed earlier. Generally, the annualized cost of owning capital plant and equipment must be recovered by the sum of the interest paid to debt holders, dividends paid to stock holders, and retained earnings. Since environmental control expenditures are not expected to produce a profit for a firm, it is unreasonable to expect equity investments to be made in them. Thus, it is common to assume that all capital expenditures for pollution control are financed by debt financing and to assign costs accordingly. (PEDCo, 1979, p. 53)

Both capital and operating costs are sensitive to scale economies in production and to the size of the firm in which they occur. In a regulatory analysis, one must analyze plants of a size typifying those existing in the industry in the case of retrofit requirements, or those expected to be built in the industry in the case of requirements for new plants. Scale factors for estimating the effects of facility size on costs are also published as rules of thumb, which are usually dimensionless exponents to be applied to capacity ratios. Typical values of such exponents are shown in Table 3 taken from Desai (1981). For example, if an agitator of one size is estimated to cost \$5,000, one that is three times as large would be expected to cost $(3)^{0.5}$ or 1.73 times as much, or about \$8,650.

Table 3

Recommended exponents for scaling equipment costs

Equipment	n values
Air Fins (coolers)	0.80
Agitator	0.50
Blower	0.65
Compressors, reciprocating and centrifugal	0.75
Conveyor	0.70
Drums	0.65
Dryer	0.50
Ejector (5-stage)	0.50
Heaters	0.80
Heat exchangers	0.60
Pumps	0.60
Refrigeration unit	0.75
Tanks	0.70
Towers	0.70

Source: Desai (1981)

2.2 Other Firm Level Costs

In addition to direct outlays for plant and equipment needed for compliance, regulation can impose other kinds of costs on the firm. These include the costs of lost production, of reduced productivity, of additional administration, of some plant closings, and of some kinds of changes in the firm's competitive strategy.

The treatment of lost production due to regulation is difficult. If a regulation does not cause price changes, then the value of lost production is simply equal to the amount of lost income minus the recurring expenditures of production. Some commentators argue that the value to the firm of lost production depends on the capacity utilization in the firm. (EPA, 1979) If the production that is lost during a period of regulatory changeover can be made up by increasing the operating rate of existing equipment before or after the changeover is made, then lost production may impose no costs whatsoever. Furthermore, it may be possible to install pollution control devices during normal maintenance periods, which would also create no costs or lost production. (PEDCo, 1979) Of course, some pollution control equipment permanently impairs plant capacity, and will impose costs if the plant could otherwise operate profitably at higher throughput.

If the engineering cost analysis is performed correctly, it should take into account the costs to the firm of changes in the productivities of labor, energy, and raw material inputs. However, if such lost productivity arises from the diversion of managerial resources from managing production to managing regulatory compliance, then there may be spillovers in which other nonregulated aspects of the firm also suffer a productivity loss. Currently, there is no known way to estimate such losses.

To meet regulatory requirements, firms must generally not only install equipment or change processes but also engage in a continuing series of activities related to monitoring, assessing, and reporting on the performance of compliance technologies. These costs must be considered real costs faced by the firm under regulation.

Within the static framework, plant closures have been a major item of analytic concern. Depending on the structure of the regulated industry and on the markets available to its firms, the imposition of new costs through regulation may serve to make one or more of the firms in the industry no longer profitable at prices the market will bear. From the static point of view, if a firm can no longer achieve an acceptable rate of return on its assets following regulation, that firm can be expected to close or to leave the line of business that is regulated. However, such an analysis assumes that firms have no slack resources and no ability to meet increased costs by using new technology. Thus, plant closure predictions based on static analyses are likely to be overly pessimistic. Furthermore, while plant closings may impose substantial costs on particular workers or communities, the cost to the regulated firm may be recoverable in part by shifting its assets to different purposes.

One of the more subtle impacts of regulation on the firm is that regulation can cause a firm to change its competitive strategy. This can be good or bad for the firm, depending on its original condition and on the new strategy that it adopts. For example, for many years the American auto industry had followed a competitive strategy of annual design change, standardized technology, and low price. New technologies and performance features were de-emphasized in American automobiles. Environmental and fuel economy regulations have caused the domestic automobile industry to shift its attention from styling and price to performance and new technology as elements of their competitive strategies. According to some commentators, this shift has been a positive one for the American industry, assisting it in coping with the challenge of Japanese and European imports. On the other hand, a regulation which causes a dynamic, rapidly changing firm to shift its strategy from growth and major change to consolidation and incremental change imposes long-run costs on the firm over and above those of compliance. This can happen, for example, if a regulation requires all the firms in a regulated industry to adopt a particular control device or process technology for compliance purposes.

3.0 The Dynamic Analysis of Firm-Level Costs: Technological Innovation and Change

The engineering economics and cost estimation approaches to analysis of the cost of industrial processes discussed in Section 2 are based on a snapshot view of the costs of technologies that are currently in use or whose cost parameters are anticipated by the state of the art of existing technology. When a private firm makes a decision to invest in a new process, it is entirely appropriate that such static analyses be used to define the costs for the firm's own cost/benefit decision model.* However, the problem faced by regulatory analysts and decisionmakers is different because (1) the technological responses of the firms in an industry to a regulation are expected to evolve over a significant period of time, (2) some firms in the industry, or that supply or depend on the industry, will develop substantially new and improved control and/or process technologies, and (3) a number of firms in the industry will be investing in the same or similar technologies at about the same time. These phenomena tend to cause the actual costs of purchasing and operating pollution control technologies or improved process technologies to be different from those that would be anticipated by a static engineering cost analysis.

This section examines the conceptual background and some empirical evidence for the impact of these dynamic phenomena on the cost of complying with regulation. First, it examines the importance of learning and experience in causing incremental reductions in the cost of operating technologies. Second, it examines how technological innovation, that is, the development, adoption and use of new technologies, influences regulatory compliance costs.

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* In more sophisticated analyses of individual firm investment decisions, there is a growing interest in anticipating cost reductions due to learning and innovation over the lifetime of a proposed project.

Third, it examines how the shift in demand for equipment created by regulation tends to change the prices of control technologies and process inputs. Finally, it discusses the conflict that can arise for a firm in the long run between cost-reduction and performance-improvement strategies that focus on learning and on technological innovation, as well as the conflict between the cost-reducing and cost-increasing phenomena discussed earlier.

3.1 The Effects of Learning and Experience on Compliance Costs

3.1.1 The Nature of the Learning Curve

It is well known that the cost of performing any task in an organization tends to decline with repetition of the task. In many cases, a plot of the cost of performing a task versus the logarithm of the number of times the task is performed is a straight line. With every doubling of the number of performances of the task, its costs are reduced by a relatively constant fraction. First noticed in the 1920s in connection with the production of aircraft, the learning curve phenomenon has been generalized to encompass nearly all industrial activity. Typically, when the task to be performed involves a large labor content, the unit cost declines by 20 or 30% for every doubling of output. That is to say, the cost at the end of a doubling period is only 70 or 80% of the cost at the beginning of the period. When the task is based on a high proportion of machine input, the decline tends to be more gradual--in the neighborhood of 90% of the original cost at the end of every doubling period. (Hirschmann, 1964)

Learning occurs in organizations. It is the manifestation of the fact that employees in a firm from top management to hourly workers become more experienced and seek shortcuts to make their individual tasks easier and more effective. Such learning happens quite apart from any effort to make major improvements in technology and is distinct from the increases in productivity and quality or reductions in cost that occur when substantially different kinds of equipment are installed in a plant. In this sense, learning is indistinguishable from what is often called incremental innovation.

While learning is well established in assembly-type industries, it is less intuitively related to the continuous process technologies used in the industries with significant pollution problems and also used to control air and water effluents. Nevertheless, when examined carefully the evidence supports the existence of learning phenomena even within such facilities as petroleum refineries and petrochemical plants. (Hirschmann, 2964) Even with a well-established petrochemical plant or petroleum refinery, ways are found over time to increase the output of the facility with only small capital investments. This happens not only because the workers and managers of the plant learn how better to schedule and operate the facility, but also because engineers are not able to completely specify the performance of such facilities in advance. Generally, such facilities can produce at a higher rate than originally intended, subject to the removal of the bottlenecks that are found to constrict production in sequential processing operations. As the bottlenecks are eliminated by investments or by changes in operating parameters, production increases, but at a slower rate as output accumulates, again following a semi-logarithmic relationship. (Bodde, 1976)

An important finding from research on learning and experience curves is that, while learning appears to be automatic, it nevertheless requires repeated production of the same product, the continual attention of management, and the continual application of resources. Furthermore, while at any time the managers and engineers are not able to anticipate how costs will be reduced in the future, for learning to occur they must have faith that costs will go down. If everyone believes that a cost plateau has been achieved, then, indeed, costs are unlikely to decline.

Hirschmann has summarized the results of learning research in the form of what he calls "learning curve doctrine":

1. Where there is life, there can be learning.

2. The more complex the life, the greater the rate of learning. Man-paced operations are more susceptible to learning or can give greater rates of progress than machine-paced operations.

3. The rate of learning can be sufficiently regular to be predictive. Operations can develop trends which are characteristic of themselves. Projecting such established trends is more valid than assuming level performance or no learning.

4. Learning is related to the dynamic context of the environment. Faith and incentive stimulate progress, and provide the drive to exert the energy, resourcefulness, skill, and persistence needed to bring it about. Conversely, the "ceiling psychology" and the tendency to maintain the status quo, or not to rock the boat, inhibit learning. (Hirschmann, 1964, p. 138)

3.1.2 Learning and Regulatory Compliance

It is reasonable to expect that the learning curve phenomenon will apply to regulatory compliance costs in at least two ways. First, it is reasonable to expect that the costs of operating an existing pollution control facility will be reduced over time as operators and managers learn to make the facility perform better. If the pollution control facility is attached to a production plant whose output is increasing, then the burden of pollution control imposed on the control facility will also be increasing, and it will be scrutinized for possible improvements in performance and reductions in cost in the same way that the main part of the plant is examined. (Of course, the firm also has the option to allow the performance of the pollution control facility to degrade over time, risking an ever-increasing probability of violation of the standard. However, even if this happens, the cost of pollution control per unit of output will decline from the firm's perspective.)

Learning in pollution control may occur in another way. In many cases, pollution control equipment is bought from a specialized vendor. In this situation, learning occurs not only in the operating plant, but also in the vendor firm that makes the pollution control devices. For example, it seems reasonable to expect that, all other things remaining constant, the cost of building and installing the 100th cooling tower for electric power plants will be less than the cost of installing the first, the second, the fourth, or the eighth such tower. Since most pollution control devices are made by assembly industries, one could expect learning to proceed along a 70 or 80% learning curve rather than the more gradual 90% learning curve typical of process firms.

Learning phenomena in vendor firms, which may influence the prices charged for control equipment, depend on the underlying market structure. In ordinary rivalrous markets, if vendors anticipate learning, they may set initial prices lower than costs to establish a market position. If they enjoy a monopoly position vendors may retain the "excess" profits that accrue as costs decline due to learning by keeping prices constant. Any such noncompetitive behavior causes a divergence between the private (regulated firm) and social costs of regulation that should be considered by regulatory analysts. Unfortunately, no data base exists for assessing and forecasting vendor learning and associated price effects.

Since effective learning depends on a relatively stable market for the product, the demand for pollution control created by a regulatory regime should remain relatively stable if learning is to be effective. This does not necessarily mean that a standard must be fixed for the foreseeable future but that the rate of expected improvement is well established or that the mechanisms that trigger changes in the regulation are well known and understood. One of the weaknesses of command and control regulations that establish standards of performance is that such standards may tend to become ceilings on what is demanded from vendors and from operators, managers, and technical people in a firm. Once compliance is achieved, attention is turned to other matters and cost reduction and performance improvement through learning are inhibited. Of course, the costs of operating pollution control devices present a continual incentive for improvement. Economic incentive approaches to regulation can bolster this incentive, while avoiding establishment of a celing on performance. (See Section 6 for further discussion of the relationship of regulatory design to learning phenomena.)

3.2 Technological Innovation and Compliance Costs

3.2.1 The Nature and Sources of Technological Innovation

Technological innovation is the process of development, adoption, and use of technology that is new to the world, to the industry, or to the firm. Technological innovation includes new technologies that perform existing tasks more effectively or at lower costs, as well as technologies that allow us to accomplish entirely new tasks. Technological innovation occurs both in response to new opportunties created by advances in science and as the response of a firm that experiences the pressure of a need to change. Research and development (R&D) contributes to technological innovation by providing the bases for the generation of entirely new concepts for continual learning and improvement of existing products and processes. However, technological innovation can often occur in a firm in which there is no organized research and development function. (Hill, 1979b)

New technologies can have a variety of origins. While in the simplest case new technologies are developed by the firms that use them, many innovations originate in supplier firms or in firms that are users of the products of the industry in which the innovation occurs. For example, innovations in the aircraft industry may be supplied by the producers of engines or of electronic equipment, and new chemicals may be developed by the industrial customers of chemical-producing firms. As an industry grows and matures, the locus of major innovation shifts from new firms, to existing firms, to new entrants to the industry.

There is considerable evidence that small firms, new firms, and new entrants to an industry play major, if not dominant roles in innovation. (Utterback, 1979) This has been found to be true even in the case of the response of auto firms overseas to U.S. safety, emissions, and fuel economy regulations. (Ashford, Heaton, et al., 1981)

3.2.2 The Interactions of Technological Innovations and Regulations

Technological innovation affects both the costs and benefits of regulatory programs. At the same time, the design of a regulatory program can profoundly influence the innovative behavior of a regulated firm. (See Hill et al., 1975; Ashford, Heaton, and Priest, 1979; Grabowski and Vernon, 1979; a series of papers in Hill, 1979a; and Hill, 1979b, for reviews of the interactions of regulation and technological innovation.)

It is useful to consider a four-fold classification of the interactions of Government regulation and technological innovation. First, the rapid pace of technological innovation in the 20th century has blessed us with the technological systems whose hazardous side effects and great power are at the heart of the vastly incrased scope of Government regulation of the last two decades in all industrialized countries. Second, technological innovation can reduce the costs of regulatory compliance by providing new control technologies or new production processes that are more effective, less costly, or inherently cleaner than existing technologies. Third, regulation may divert financial and human resources from the ordinary course of technological innovation activities in industry or it may establish barriers to new ideas and, thus, inhibit innovation for ordinary business purposes. Fourth, at other times new Government regulations may stimulate technological innovation in industry and provide benefits to regulated firms even in areas other than those related to compliance.

This paper is concerned primarily with the second point above (innovation to reduce compliance costs) and to a lesser extent with the third and fourth (regulation can inhibit or stimulate innovation). It also examines how regulation can be designed so as to encourage the development and use of better control or process technologies for compliance purposes.

A careful examination of the first point (innovation creates the need for regulation) lies beyond the scope of this paper. Suffice it to say, however, that regulation has emerged, not as part of a general trend toward misguided interference in private affairs by big Government, but as an effective social mechanism for exerting control over the threats to these affairs by powerful technologies. Similarly, it is beyond the scope of this paper to review the theory and evidence on how regulation inhibits innovation for ordinary business purposes (a perspective well-represented by Grabowski and Vernon, 1979) or of how regulation stimulates innovation for main business purposes (see Hill, 1980, for an elaboration of this perspective and Royston, 1980, for an extensive set of examples).

3.2.3 Technological Innovation and Compliance Costs: Some Examples

Let us examine a hypothetical example of how technological innovation can affect regulatory compliance costs. Consider the case of air pollution control from a textile dyeing and finishing plant. If the basic dyeing process is not changed in response to pollution control demands, it is likely that the plant will have to install ventilating systems as well as devices for recovering or destroying chemical vapors in the exhaust air. It is unlikely that the textile firm would develop such systems and devices itself; rather, it would approach the existing vendors of ventilation systems to purchase control technologies. The ventilating system vendors in turn would probably try to adapt their existing lines of equipment to meet the needs of textile companies. They might engage in R&D to develop more effective or cheaper control technologies, but major advances might well come from firms that had not been involved in the ventilating equipment field at all. Alternatively, firms that sell textile finishing or dyeing chemicals to the textile industry might do research on methods of vapor recovery in the textile industry in order to protect the markets for their existing chemical lines. Or, they might do research on water-based textile chemicals that do not generate harmful vapors. Similarly, fiber makers might search for new fiber compositions or yarn types that could use entirely different methods of dyeing or finishing.

The regulatory analyst who seeks estimates of the cost of compliance with an emission standard for organic vapors from textile mills from the vendors of ventilating equipment is not likely to be aware of the R&D efforts of suppliers and consumers of fibers, textiles, textile chemicals, and textile machinery to develop better fibers, ventilating technologies, dyeing methods, or recovery systems, that will allow for lower cost technologies. Only if given extraordinary time, resources, and access to industry information will the regulatory analyst be able to acquire this knowledge. Even then, the more important the advance, the less likely is the analyst, or anyone else, to be able to anticipate it in advance. The result is likely to be a systematic overestimate of the ultimate cost of compliance. We currently have no basis for adjusting these overestimates.

Two actual examples might serve to illustrate dramatically the impact of technological innovation on regulatory compliance cost. The first example, taken from Dewees (1978), illustrates how the cost of control of automobile pollution has shifted as control technologies have been improved. Figure 1 illustrates these cost improvements over time. Each curve on Figure 1 represents the marginal costs of achieving each level of control using technologies available in each year. ("Net Percent Controlled" refers to a weighted average percent reduction of emissions of the three pollutants, CO, HC and NOx, compared with emissions from uncontrolled vehicles.) Obviously, in

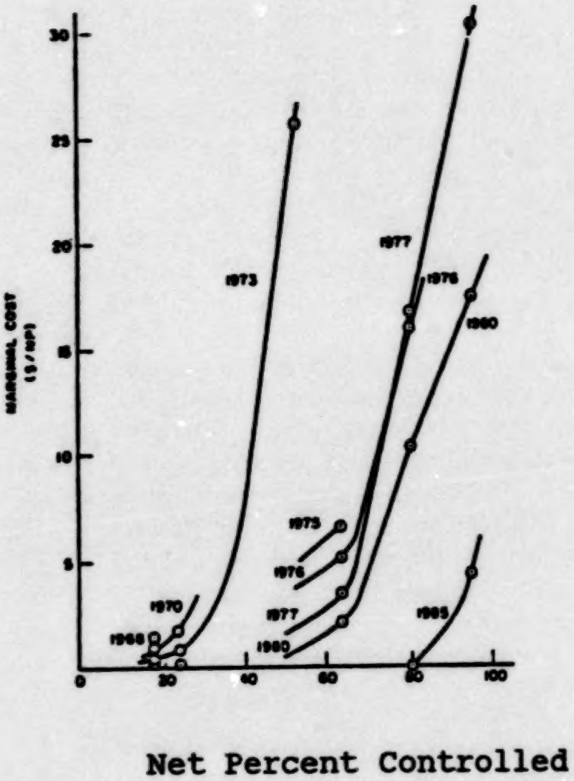

Figure 1. Marginal costs of standards at different dates.

Source: Dewees (1978)

any year, more control has cost more. But, equally obviously, over the 15-year period the costs of achieving a particular level of control have declined dramatically. The declines in the 1968-75 period arose from minor modifications of existing engine designs and from adoption of the catalytic converter--an end-of-pipe control technology. After 1975, the declines arose from major changes in engine technology including lean-burn and stratified charge engines. (It should be noted that parts of Figure 1 are Dewees' estimates of potential control costs and do not necessarily reflect actual technologies adopted by the manufacturers. No attempt has been made by this author to reconcile Dewees' paper with the paper by Joseph A. Vasquez in this volume.)

Dewees (1978) points out that currently we are not able to forecast the rate at which such curves appear or shift. This conclusion is consistent with the broader view that major technological advances are inherently unpredictable. (Klein, 1977, 1979) But, the situation is not necessarily hopeless for the regulatory analyst. For incremental improvements, the theory of induced innovation may provide a useful framework. For example, in one empirical modeling study, it was found that technology for producing synthetic ammonia from natural gas evolved in a quite regular fashion in response to changes in the prices of input factors over a 25-year period. (Greenberg, Hill and Newburger, 1979) Furthermore, the theory of induced innovation has been shown to apply in a number of other situations, especially in agricultural technology. (Binswanger and Ruttan, 1978) However, aside from some rather pro-forma modeling exercises by McCain (1978) and Magat (1978), no general guidelines have been developed that would facilitate prediction of the quantitative response of the costs or performance of new technologies to regulatory stimuli.

The second example is the control of worker exposure to vinyl chloride in polyvinyl chloride (PVC) manufacturing. Initial estimates of the cost of regulation were extraordinarily large, on the order of 65 to 90 billion dollars of lost sales and production. (A.D. Little, 1974) However, once the industry had turned its attention to the problem of worker exposure, not only were control cost orders of magnitude lower than estimated, but some firms were able to produce PVC at a lower cost than before the regulatory stimulus. (Ashford et al., 1980) This happened in part because the work exposure standard accelerated the adoption of new technology which was both more productive and safer. This result is consistent with Dewees' notion that regulation can accelerate the adoption of "dusty technology" already on the shelf. (Dewees, 1978) In another empirical study of chemical industry response to regulation, Ashford, Heaton, and Priest (1979) report that the majority of compliance responses used technology that was nearly commercial before regulation. (This finding, however, does not mean that an analyst could have found out about these "dusty technologies" for ex ante regulatory analysis purposes.)

3.2.4 Technology-Forcing Regulation

In several cases in the last decade Congress has adopted environmental legislation mandating the use of technologies that are more effective than those commercially available or in use at the time the legislation was passed.

Such regulation is commonly known as "technology-forcing" regulation. It can be viewed as being intended to cause the generation of entirely new technology or to accelerate the movement of "dusty technology" from the shelf to applications. However, Congress has rarely, if ever, mandated the use of technologies whose performance is entirely out of sight at the time the legislation is adopted. Rather, it has usually acted on the knowledge that technologies with performance in the desired range are at least at the developmental stage, and the purpose of the legislation is to accelerate their development and adoption.

Nevertheless, sometimes the technology ultimately adopted by the regulated firms is different from that anticipated at the time the technology-forcing regulations were adopted. The Clean Air Act mobile source control provisions provide an example of this phenomenon. When the Act was adopted in 1970, Congress could not have reasonably anticipated the oxygen-sensor, microprocessor controlled fuel delivery, three-way catalyst system that has been adopted by many auto firms since 1976. Yet that technology was ultimately adopted, rather than the electric car, the Sterling engine, or the gas turbine, which were under discussion in 1970. This discussion illustrates again the unpredictability of significant technological advance.

3.3 The Effect of Regulatory Demand on the Cost of Process Inputs and Techniques

Suppose that a cost engineer wishes to project the cost of a tertiary treatment system for water effluents from an electroplating plant. Following the usual procedures of engineering cost analysis, the analyst would describe at an appropriate level of detail the items of plant and equipment needed to perform the task for a model plant with specified performance parameters and size characteristics. Such a treatment facility might involve the construction of buildings, the erection of concrete settling tanks, and the purchase of equipment such as pumps, filters, and the like. The analyst would use ordinary procedures and handbooks to estimate the costs of structures and buildings and would contact equipment vendors for estimates of the prices of the various items of mechanical equipment and electrical control systems. Because the analyst would be proposing to purchase only a small number of items, vendors would be likely to quote current prices. In view of the procedures used by cost engineers, these equipment price quotes are the foundation upon which all other costs are developed.

Now suppose, however, that all of the firms in the industry will be installing similar equipment at about the same time in response to a new regulation under the Federal Water Pollution Control Act. The effect of the regulation is to cause a step increase in demand for the items of equipment necessary for the control facility. In economic terms, the demand curve has been shifted upward. As a result, the prices that firms will have to pay for equipment will be higher than quotes for a single purchase.

The importance of such demand-induced price changes for regulatory compliance costs has been examined in a series of studies performed by Thompson and colleagues at the University of Houston. For example, in work summarized in Thompson (1979) it was found that water treatment costs might be increased several-fold if uniform technology standards were applied to all industries nation-wide. It should be noted that a substantial and expensive modeling effort may be needed to estimate such cost increases credibly.

The phenomenon of demand-induced increases in regulatory compliance costs should not be confused with the phenomenon of systematic underestimation of project capital costs that has been observed in a wide range of major process plant projects. (Merrow, Phillips and Myers, 1981) While military cost overruns have been highly visible, undercosting is not limited to that sphere. For major new process plants and energy conversion technologies such as coal gasification and oil shale recovery, the capital cost estimates tend to escalate at a rate several times higher than the nominal rate of inflation. For major new technologies whose performance is unknown or uncertain, cost engineers systematically underestimate the difficulty of bringing those technologies on-line and, thus, systematically underestimate their costs. Merrow and colleagues found that the greatest source of error is use of inappropriate cost estimating methodologies, and that such factors as scope changes, inflation, environmental regulations, management practices, strikes, and bad weather are much less significant as contributors to underestimates of capital costs. The proponents of new technologies fail to grasp the cost implications of including multiple untried technologies in major first-of-a-kind projects.*

3.4 The Incompatibility of Learning and Technological Innovation Strategies

Recent research has shown that firms which adopt a strategy based on incremental improvements and learning curve phenomena may find themselves unable to make the major changes necessary to adapt to substantial changes in scientific understanding, market demand, and social requirements over the long run. Similarly, firms that emphasize major technological advances are not able to follow a strategy of incremental improvement in costs and productivity over time. Klein (1979) has called the ability to adapt to major changes in the environment "macro-stability" and the ability to make continued small changes "micro-stability." He asserts that there is a direct tradeoff for any firm between micro- and macro-stability.

The classic study in this area is by Abernathy and colleagues, who studied the dilemma faced by the Ford Motor Company in the 1920s as the Model T Ford reached the end of its commercial life. (Abernathy and Wayne, 1974, and Abernathy, 1978) Ford adopted the strategy of making continual incremental changes in the Model T, while the basic concept remained fixed. As a result of the incremental improvement strategy, the price in constant dollars of the Model T declined by a factor of nearly four over its 15-year life. However, when Ford was faced with major competition from General Motors in the early 1920s, the very efficient but inflexible structure it had established for making Model T's was almost unable to make the major change necessary to adapt to the new market conditions imposed by GM's annual model change strategy. Thus, Ford faced a major innovation crisis in the early 1920s as a result of its earlier successful strategy of incremental productivity improvement.

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*Section 3.5 addresses the apparent conflict between the cost-reducing contributions of learning and innovation and the cost-increasing effects of innovation in first-of-a-kind facilities.

A similar crisis was experienced by the Volkswagen Corporation in the early 1970s as the "Beetle" reached the end of its 25-year commercial life. Volkswagen was almost unable to adapt to the changed demands of styling, performance, safety, and fuel economy imposed on it by its competitors and by Government regulations in the early 1970s.

Firms generally follow one of a small number of strategies with respect to technological change. Some firms try to maintain a continual flow of new technologies having significantly improved performance or reduced cost. Others depend on long production runs of relatively standard items that allow them to take advantage of both economies of scale and incremental learning over time. Neither strategy is necessarily better, but, as noted above, firms can not excel at both simultaneously--a balance is required.

The technology strategies of firms that make or operate pollution control equipment or less-polluting processes have not yet become generally apparent. There is some evidence that the technological responses of firms to regulatory requirements may not be conditioned by their pre-existing technology strategies. In a study of the response of the chemical industry to environmental requirements, Ashford and Heaton (1979) found that both "fluid" and "rigid" firms tended to make changes in technologies that could be considered equally novel. (In this study a fluid firm is one that is engaged in rapid technological change while a rigid firm uses a more established and less rapidly changing technology.) Both rigid and fluid firms were likely to use technologies whose parameters were already known. These results suggest that the design of regulation need not take into account the state of the technology in the regulated industry to achieve an effective response to regulatory requirements.

It is not clear whether these findings for the chemical industry can be extrapolated to industry generally, however. For example, in a mature industry with relatively slowly changing technology and relatively small numbers of new entrants, it is unlikely that the firms in the industry would develop pollution control methods with lower costs than those they might be able to purchase off the shelf. In this case, regulation might be more effective and cause lower costs if it were designed to encourage firms from outside the industry to develop pollution control equipment and cleaner process technologies. This might be done, for example, by Government support of pollution control R&D in firms not traditionally associated with the regulated industry, or in laboratories and universities that encourage the spin-off of new firms.

Furthermore, in these rigid industries, design-based standards may be most effective. On the other hand, industries whose technology base is more fluid may respond more effectively to performance standards that encourage major change. More research on industrial responses is needed to determine under what circumstances it would be important for the technological demands of regulation to be coherent with the dominant technology strategy of firms in the regulated industry.

3.5 Resolving the Cost-Reducing and Cost-Increasing Effects of Innovation

This section has emphasized how technological innovation and learning can be expected to reduce the costs of regulatory compliance below those predicted by static engineering cost analysis. But, at the same time, mention has been made of the work of Merrow and colleagues (1981) on cost overruns, which shows that cost estimates for new, technological projects are often quite low. These arguments might appear to be contradictory, but there is a simple resolution of the apparent difference.

In the compliance innovation case, the baseline cost estimates are usually made for relatively well-known, state-of-the-art, end-of-pipe technologies. These approaches are usually known to work and have relatively well-defined costs and performance parameters. Within the limitations of "study" estimates for model plants noted in Section 2, their costs can be estimated with some confidence. Subsequently, compliance innovations are only successful if they can offer lower-cost solutions--while one firm might experience cost overruns trying a new approach to compliance, a new technique that is found to be more expensive than well-known approaches is unlikely to be widely adopted. Thus, innovation can not raise compliance costs in the aggregate significantly higher than end-of-pipe costs.

In the cost overrun cases examined by Merrow, the excess overruns arise from the presence of key elements of untried technology in the baseline first-of-a-kind plant. Either there is no prior, well-understood baseline case (as, for example, in advanced weaponry) or the cost constraint of the well-known baseline case is artifically suppressed (as, for example, in the synthetic fuels case). Thus, only in cases where there is no well-understood control technology at the time the regulatory analysis is performed, could innovation be expected to cause costs of compliance to exceed those projected ex ante.

4.0 The Analysis of Industry-Level Costs

The two previous sections have discussed the analysis of the costs of compliance with regulation in individual firms. These must be aggregated across an industry or across geographic regions in order to estimate the aggregate cost of a regulatory requirement for an industry or the Nation. This section discusses two major considerations in aggregation. First, it examines the question of access to compliance cost estimates and how such data should be acquired. Then it discusses several issues that arise in aggregating cost estimates across firms.

4.1 Sources of Compliance Cost Data

There are two basic ways to acquire data for compliance costs estimates. The first is to survey firms in the regulated industry for their estimates of what a proposed regulation will cost at each of their facilities. The second is to do a detailed engineering cost analysis for model plants, modified as appropriate to account for innovation and learning. The model plant approach is generally used.

There are at least three problems with the industry survey approach. First, unless both the Government agency (or its contractor) and the responding firms pay a great deal of attention to defining the scope of the compliance technology, it is unlikely that cost information will be presented on a sufficiently consistent basis to allow for comparisons across firms or against independent estimates. Second, there is an obvious incentive for firms threatened with regulation to overestimate their costs of compliance. Third, agencies have limited or no authority to compel firms to respond to a cost survey, so the sampling bias in the responses is likely to favor an overestimate of total costs.

There are also difficulties with the engineering cost analysis approach to compliance costs. First, for many pollution control technologies there are no standard sources of information because there is little or no experience upon which to assess their costs. Thus, the analyst must make a greater number of assumptions and must operate in a more uncertain cost environment than the engineering cost analyst who is examining a standard production technology. Second, the more creative responses to environmental control requirements involve modifications in existing processes or the adoption of entirely new processes that produce fewer environmental effluents. For the most part, a regulatory analyst in an agency or its contractor is in a weak position to anticipate these more creative responses. Third, the analyst is also in a weak position to forecast the impacts of learning or incremental technological innovation on any particular compliance technology. Finally, the most effective and lowest cost approach to controlling a particular hazard may be developed and marketed by a firm which has not been part of the regulated industry or one of its supplier firms in the past. In this case, it is almost impossible for an industry respondent or a regulatory analyst to be aware of the potential of a new technology that might operate at lower cost.

As a result of the above considerations, the regulatory analyst and the regulatory decisionmaker face an important dilemma in trying to do cost analysis and in trying to base regulatory decisions on a cost/benefit criterion. The analyst and the decisionmaker are likely to be most certain about the costs of the least-creative and highest-cost environmental controls, and are likely to be least certain about the costs of the most-creative and lowest-cost approaches. Thus, in using cost/benefit analysis there is a systematic bias toward overestimating the cost of compliance with any particular regulatory requirement. Until considerable additional research is done to compare ex ante and ex post estimates of the costs of regulatory compliance, it is unlikely that there will be any basis for estimating the impacts of learning and of innovation on compliance costs in a rational way.

One initial attempt to make such comparisons was performed by Putnam, Hayes, and Bartlett (PHB, 1980) on behalf of EPA. In that study it was found that both EPA and the regulated industries make substantial errors in estimating capital costs for pollution control as compared with actual costs from survey data. The errors by EPA ranged from 26% low to 156% high, and the industry errors ranged from 25% low to 162% high. Though the error ranges are the same, the EPA estimates tend to be more accurate than those of the regulated industries. PHB did not attempt a detailed analysis of the factors and assumptions that led to the overestimates of costs ex ante. Furthermore, this study was performed at an industry-wide level and provides no guidelines or rules of thumb for correcting a static cost estimate to account for innovation and learning for a particular technology or a particular pollution control regime. While systematic prediction of technological advance is not possible (and may never be), it would appear to be important that more work be done to understand the relationship between compliance costs and the nature of the regulation, the regulated industry, and its technology.

4.2 Aggregating Costs Across Firms

Once cost estimates have been made for model plants at some level of accuracy, the regulatory cost analyst must aggregate them across all the firms now in, or likely to enter, the industry. This subsection addresses several issues that must be considered in aggregating such costs.

4.2.1 Projecting Compliance Levels

In the case of command and control regulations for air and water pollution and solid waste, it is inadequate to assume for purposes of either effectiveness (benefits) analysis or cost analysis that all the firms in the industry are or will be in compliance with the regulation at a particular time. Since most environmental control regimes involve State and local enforcement, the pattern of compliance depends on the vigor of enforcement within the various State and local jurisdictions. Furthermore, States and localities are likely to give variances to noncomplying firms as a way to take into account the financial conditions of the firms or other extenuating circumstances.

Firms will adopt a variety of postures with respect to the risk of detection of violations and the severity of the consequences of detection. Since the performance of any item of process equipment, including pollution control devices, is characterized by a probability distribution, there is always some probability, however small, that a firm will be found not to be in compliance at a particular time. Since greater equipment reliability and a consequent higher probability of being found in compliance generally costs more, a firm obviously faces a tradeoff between the costs of compliance and the costs of a violation.

Clearly, the extent of compliance resulting from enforcement behavior and firm strategies will influence the aggregate costs of compliance with a new regulation. Unfortunately, there are very few data on compliance levels and no general models for forecasting them. This is an area where there is a great need for more study.

4.2.2 Model Plants and Industry Diversity

The population of model plants for which cost estimates are made must be a fair and accurate representation of the relevant population of actual plants in the industry. For a regulation that applies to existing plants, the relevant population is, of course, the set of existing plants, less any that are expected to close for reasons unrelated to regulation before the regulation takes effect. For a requirement that applies to new plants, the analyst must anticipate the sizes and locations of plants that are likely to be built during the period for which the regulation is in effect and to which the analysis applies. In the latter case, the analyst must talk with a diverse set of students of the industry to obtain a set of scenarios for the future development of the industry.

The total costs for an industry in the aggregate, as obtained from model plant calculations, must be modified to account for such local factors as the prices of inputs in local markets, and for additional costs due to bad weather, water shortages, the conditions of soils for solid waste disposal, and so on. An accurate estimate of the cost of a regulation for an industry must take into account these local circumstances, as well as the enforcement and compliance expectations.

4.2.3 Quantity Discounts

In estimating the costs of any pollution control device, one must take into account the number of such devices to be purchased by each firm. As noted above, the simultaneous purchase of a larger number (compared with the total market) of devices to comply with a new regulation may shift the demand curve upward and thus increase the price that has to be paid by each of the regulated firms. On the other hand, list prices of standard equipment such as pumps, piping, or measurement devices may be discounted to large purchasers. Thus, one must take into account the total number purchased, the scheduling of purchases, and the pricing policies of the suppliers to get an accurate cost estimate.

5.0 Other Considerations in Cost Analysis

A fair and accurate analysis of the cost imposed on an industry by any particular regulation must take into account several other considerations discussed in this section.

5.1 Selecting an Appropriate Baseline for Comparison

The cost of any regulatory requirement is the cost of achieving some new state of industrial performance as compared with some other state. Thus, it is important not only to estimate appropriately the cost of the regulated state but also the cost of the state of nonregulation or alternative regulation. Several issues regarding the choice of an appropriate baseline for comparison have been discussed in connection with the analysis of benefits of regulation by Hattis and Ashford (CPA, 1981--see also Ashford et al., 1980) and they apply to cost analysis as well.

First, if a proposed regulation is not promulgated, other forces will often cause the polluting industry to achieve some level of environmental control. These include voluntary action to improve the firm's image, to recover valuable components of the effluent, or because of a felt corporate responsibility; the impact of political pressure by affected communities; the threat of future regulation; private legal actions brought under the common law to control the effluent; and spillover effects from other regulatory regimes that cause the industry to achieve some level of control. If any of these corollary forces is in operation, it is not appropriate to assume that a condition of unrestrained emissions is the baseline against which to compare the regulated one. Instead, the analyst must examine these other forces and estimate the costs industry is likely to incur in response to them in the absence of the proposed regulation. Only these incremental costs should be counted.

Second, there is the problem of what to do about costs when compliance with a pre-existing regulation is not complete. Hattis and Ashford have discussed this circumstance in some detail in connection with the analysis of regulatory benefits. In parallel with their discussion, it would appear to be technically and politically correct to assume that the costs of compliance with an additional regulation are represented by the difference between the cost of compliance with the new standard and the cost of compliance with the old standard. Any costs that should have been incurred to go from the current state of noncompliance to compliance with the pre-existing regulation should not be attributed to the new regulatory requirement. Similarly, of course, the cost of the new regulation should be based on a realistic assessment of the degree of compliance with it. (See Section 4.2.1)

5.2 Spillovers to Other Regulations

The existence of other supplementary or complementary regulations on an industry can affect the cost of compliance in at least two ways. For example, an air pollution standard may require changes in an industrial process that can conflict with or support other changes required to meet water pollution, solid waste, or occupational standards.

When complying with one regulation also causes a firm to comply with some other existing or proposed regulation, the costs of compliance should be allocated between the two regulatory regimes. This avoids double counting of costs and reflects a more accurate cost for the regulation under consideration.

In some circumstances the requirements of two or more coexisting regulations are incoherent and create costs of overlap. That is to say, regulation A might cost $1 million alone and regulation B might cost $2 million alone but the combination of A and B might cost $4 million. (See for example, Lave, 1981.) In such a case, the regulator may wish to examine alternatives to the regulatory designs that avoid creating an extra cost of incoherence. If such extra costs are unavoidable (such as when recovery of an air pollutant creates a new source of polluted water), it is necessary to allocate part of the extra costs of compliance to each of the two requirements. However, one should also take care not to base estimates of the costs of incoherence on the cost tradeoffs implied by the performance of existing technologies--a conceptual limitation of the Lave paper. Instead, the threat of incoherence requirements may be a stimulus for firms to seek new technologies that avoid the costs of tradeoffs along existing performance functions.

5.3 The Treatment of Joint Costs for Compliance and Protection

Frequently, changing a process technology for the purpose of regulatory compliance provides an opportunity for the firm to improve the productivity, performance, or cost of the regulated technology for ordinary business purposes. The new investment that was stimulated by the regulation may actually create an overall cost savings for the firm. (See Hill, 1980, and Royston, 1980.) In such cases, the cost of regulation should be only any marginal costs created by the regulatory requirement and not the full cost of the new production equipment or even the full cost of compliance to the extent that it has been offset by benefits gained by improved productivity.

5.4 Social Versus Private Costs

This paper is almost entirely concerned with the private costs to firms of complying with regulations. It is beyond its scope to delve into the relationship of these private costs to the true social costs of regulatory compliance. To be meaningful, cost/benefit analysis must be based on true social costs and benefits, not on private costs and benefits alone.* For example, such matters as subsidies for regulatory equipment and special tax treatment of compliance investments under the Internal Revenue Code do not change the true social costs of compliance, even though they may reduce the apparent private costs to the firm.

The regulatory cost increases faced by a firm are not paid by that firm, when they can be passed backward to suppliers or forward to consumers. Thus, the total social costs can exceed the costs paid by the regulated firm. The ability to make such cost transfers depends on the elasticities of supply and demand and the competitive conditions of the market within which the regulated firm sells. Analyses of these cost transfers are, of course, at the heart of modern welfare economic analysis. What is striking in examining the literature on welfare analysis applied to pollution control is that welfare analysts frequently apply sophisticated welfare considerations to naive estimates of private costs given by engineering cost analysis. (Similarly, of course, the engineering cost analysis rarely pays attention to welfare considerations, not even to externalities.) We have encountered no instance of regulatory analysis in which both the engineering cost analysis and the welfare analysis reflect the best of both fields.

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*An example of not considering adequately the difference between private costs and social costs is the idea for a national "regulatory budget" that would set a cap on the annual imposition of private costs by regulation. (DeMuth, 1980) From a utilitarian (social cost/benefit) perspective, the regulatory budget makes no sense. The issue is not private costs alone, but the net of social benefits over social costs.

6.0 The Effects of Regulatory Design on Compliance Costs

The first objective of any environmental regulation is to reduce risks and control hazards to human health and to the natural environment. However, a responsible regulator would also like to control such risks at the lowest cost to society. Within the limitations noted in Section 5.4 regarding social vs. private costs, this generally translates to the goal of controlling risks at the lowest cost to the regulated industry. This section considers how the design of a regulatory regime can affect the costs of compliance. It considers both command and control regulations that set standards for design or performance of technologies, and economic incentive regulations that are intended to influence the behavior of polluters by increasing the costs of polluting.

Minimizing the cost of a regulatory requirement can be considered in both static and dynamic frameworks. From a static perspective, one chooses a regulatory approach that creates the lowest possible cost while achieving the desired level of control. From a dynamic perspective, however, one hopes to create incentives for both continual cost reduction and continual improvement in the degree of control over time.* One example of an existing regulatory regime that achieves a degree of dynamic performance is the prevention of significant deterioration (PSD) provisions of the Clean Air Act. Effectively, as the available increment is consumed the PSD provisions set ever tighter standards of performance for polluters in each attainment region. Likewise, the emission offsets provisions now being implemented by EPA, to provide the opportunity for continued industrial development in nonattainment regions, require each new polluter to achieve a better level of emissions performance than the pre-existing plants from which offsets are obtained. Both of these approaches have the virtue of providing an incentive for steady improvement and thus encourage innovative approaches to environmental controls.

6.1 Command and Control Regulations

Both the institutional arrangements and the structural details of a command and control regulation affect the costs to regulated firms and their propensities to innovate.

6.1.1 Institutional Aspects of Command and Control Regulations

Congress occasionally sets regulatory standards itself, as in the passenger vehicle emission standards under the mobile source provisions of the Clean Air Act. However, the vast majority of standards setting is delegated to administrative agencies, as in the stationary source provisions of the Clean

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*Clearly, as the overall productive activity in the economy and the associated potential to pollute grow, achieving and maintaining a desired level of public health protection require continual improvement in environmental control technologies. Thus, the Nation's environmental objectives must be dynamic in the long run.

Air Act, the effluent standards under FWPCA, and the hazardous waste management standards under RCRA. It is generally believed that Congressionally-established standards provide a regulated industry with greater certainty about the emission levels to be achieved, but that they do so at the expense of a less careful consideration of the detailed tradeoffs between control levels and costs in particular industries or locations. However, experience with the frequent changes in the mobile source standards suggests that, if anything, Congressionally-mandated standards may be more erratic and uncertain than agency-promulgated standards. If this is generally true, then Congressionally-mandated standards can be expected to create high static costs and not take advantage of the dynamic effects of learning, since the control target will change frequently. More research is needed on the relative cost and innovation impacts of Congressional and agency standards.

The roles of the various levels of government in a regulatory regime also affect its costs. If nationwide standards are set at the Federal level and enforced by Federal agents, there is less chance that compliance requirements can be tailored to meet local conditions, and static costs will be higher than if standards are set and enforced locally. On the other hand, national standards help aggregate the market for pollution control equipment and make it more likely that learning and innovation will reduce overall costs of compliance over time. We are unaware of empirical studies of the tradeoff between these two effects on costs.

Government support of research and development for compliance purposes may help to reduce the costs of compliance by making cheaper technologies available to the regulated industry. On the other hand, from a dynamic point of view, heavy support of R&D by Government may undercut the private innovative efforts that might otherwise take place and thus weaken the incentive for private firms to develop better technologies. Furthermore, some of the incentives present in publicly-funded R&D programs emphasize incremental improvements in existing technologies and discourage the risk-taking needed to make major technological advances. These incentives include the paradigm-bound peer review system, the fact that funding agency managers are not rewarded for major advance but are penalized for failure, and the proper demand for high accountability in spending the public's funds. Thus, while R&D support might appear to be desirable at first, it may be better for Government to enforce standards vigorously and to reduce its involvement in R&D funding to the level necessary to maintain agency staff capability, identify new problems, and develop controls only for fragmented or marginal markets of high social value.

Government can help ensure markets for major new pollution control technologies if it structures regulations to require the use of best available technologies, rather than to achieve a particular standard of performance at a point in time. However, in requiring best available technology, it is important not to create disincentives for industry to develop new technologies. For example, if firms know that any better technology will have to be used in all of their facilities, they may avoid developing and promoting better control technologies. Thus, "best available technology" can not be taken literally by regulatory agencies. Similarly, a Government mandate to license control of technology patents to competitors, in order to facilitate the diffusion of new control technologies, may weaken the financial incentives that encourage firms to develop improved control technologies.

6.1.2 Structural Details of Command and Control Regulations

The type of standard influences costs, cost analysis, and innovation. Design standards, which specify the methods to be used to reduce pollution, provide the most easily assessed costs since the analyst can describe the technology that is to be costed.* Enforcement costs are substantially lower than for performance standards, because once an inspector learns about the design, inspections consume less time than is needed to measure performance.** However, in principle compliance costs are expected to be high for design standards.

Performance standards, which specify only the allowable emission levels, allow use of various technologies to reach the goal of the regulation and, in principle, allow for achieving lower compliance costs than design standards, in both static and dynamic terms. Performance standards make the job of the regulatory analyst in calculating compliance costs more difficult, because the analyst must examine all possible approaches and forecast which firms will employ each of them. There is no practical way to undertake a comprehensive analysis of the cost of a performance standard unless the responses of all firms are assumed to be similar. If different control systems are used to meet performance standards, inspectors may have a difficult time determining compliance, and administrative costs will be high.

It is generally believed that performance standards are better than design standards for encouraging the development and adoption of better pollution control technologies.*** The argument is that a performance standard allows industry greater latitude for creative response to regulatory requirements. However, the structure of the regulated industry can modify this general conclusion. For example, some polluting industries are highly fragmented, consisting of many small firms whose production technologies differ only slightly. Such firms do not have the resources necessary to take advantage of the flexibility of performance standards. In fact, the testing and evaluation necessary to meet a performance standard may impose a higher cost burden on such firms than simply defining compliance for them as the adoption and use of technologies of specific design. Furthermore, if such industries can use a standard design, this may allow the firms who supply those designs to learn and to sell a large enough number of units to support an R&D effort to improve the performance or reduce the cost of those control technologies. On the other hand, performance standards can be more effective and impose much lower costs for industries that are in a stage of rapid growth and development and whose basic process technologies are evolving rapidly.*

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* This is not to suggest that the ease of analysis should lead society to favor design over performance standards, but only that a regulatory decision procedure based on cost/benefit analysis will unduly favor design standards.

**Frequently, regulators have chosen design over performance standards on effectiveness grounds, arguing that enforcing performance standards in the field can be impossibly costly, time-consuming, or hazardous. Examples can be found in areas as diverse as building codes and hazardous cargo regulations in coastal shipping.

***The distinction between design and performance standards is not so clear in practice. Often, agencies describe at least one design that will be acceptable in meeting a performance standard. Also, actual standards are often a hybrid of design and performance types.

The detailed structure of a regulatory standard can influence the reliability, and therefore the redundancy and capacity of control systems required for compliance. Air and water quality standards are usually structured in terms of the maximum allowable number of exceptional episodes per year. For example, a particular level of emissions might be allowed to be exceeded only for 4-hour periods, three times a year. It may make a large difference to the compliance cost whether a given level can be exceeded for 4 hours or 6 hours, or whether it can be exceeded twice a year or five times a year. The influence of this design parameter on compliance cost depends on the probability distributions of the performance of the production technology, the control technology, and the monitoring and enforcement mechanisms. Against such cost considerations must be traded off both the public health implications of allowing variances from the standard, and the implications of such reliability distributions for the operational practices adopted by firms. Operational practices can be important if the firm takes advantage of an exception provision of a standard to periodically clean dirty items of equipment or to adopt a generally lower standard of care.

Finally, the timing and phasing of regulatory requirements may have a large effect on the propensity and ability of regulated firms to learn or to innovate in order to reduce compliance costs. If the time allowed for compliance is too short, the regulation will induce adoption of end-of-pipe approaches that result in no significant change in operating procedures, except that a system that may interfere with the production process may be attached to the end of an emission pipe. End-of-pipe approaches, which often appear to be the least expensive approach in the short run, can easily be assessed by cost analysts, but they often create unexpected problems for the process. The hidden costs of end-of-pipe approaches are that they often fail to achieve the objective, require substantial maintenance, and are viewed as "that mismatched stuff at the end of the pipe that screws everything up."

On the other hand, longer compliance delays that allow adequate time for major changes in processes and control technologies do not disrupt normal behavior, but also may not impress the firm as serious. If it is not perceived as serious, as the deadline for compliance approaches the effective time for compliance becomes short and add-ons again dominate. While longer delays provide the opportunity for technological innovation, small innovators and new entrants can not undertake a technically risky project if potential rewards are years away. Of course, longer compliance delays also mean that the hazard persists and continues to threaten injury and impose costs.

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*Such innovative industries can pose special problems for responsible regulation, if unnecessary inhibition of desirable innovation is to be avoided. See, for example, Hill, Andrews, Frenkel, et al. (1980) and the synfuels regulation strategies discussed by the EPA/DOE Interagency Energy/Environment Task Force.

Phasing of a standard, which is intended to achieve some control while major improvement is worked on, can induce the same sort of behavior as a short compliance time. Furthermore, each step of a phased-in regulation requires a marginal reduction in emissions, which is met by marginal technical change. Again costs are lower in the short term. But if they fail to align technically with evolving market trends, marginal changes can be expensive approaches for the firm and society.

The response of the automobile industry to the Clean Air Act requirements provides a good example of this problem. (Kagan, 1979) At each step of the phased-in Clean Air Act requirements the auto companies made another marginal change. The concept of major technical change to meet evolving market needs for low emissions and high fuel economy was not widely accepted until the late 1970s. The U.S. automobile industry is now paying the cost of its earlier narrow view of compliance by having to engage in crash programs to meet regulations and market demands.

In a recent study of the response of the foreign automobile industry to U.S. regulatory requirements, we found that the Swedish automobile companies, SAAB and Volvo, made especially creative responses to U.S. air pollution control requirements early in the cycle of phased standards under the Clean Air Act because they felt unable to cope with a frequently changing standard in a marginal way. (Hill and Andrews, 1980) Early in the game they developed and adopted a technology that would be able to achieve the ultimate levels of control expected under the Clear Air Act, a technology using a 3-way catalyst, oxygen sensor, and microprocessor feedback control of fuel and air supply using fuel injection. They were unable to take advantage of the phased-in application of standards under the Act and took the chance on making a major advance instead. From their perspective, it was fortunate that they succeeded.

More generally, regulatory requirements that are tightened in successive steps over time may work against learning and technological innovation by the regulated industry and its suppliers. The regulated firms may find themselves so busy coping with the immediate requirements of marginally improved performance that they can never turn their attention to making the kinds of major changes that would allow them to meet future requirements at lower costs. On the other hand, firms may choose to delay compliance with major changes in the hope that the regulation will be rolled back or that another firm will develop a cheaper compliance technology in the interim. There is a need for further research to understand the relationship between timing and phasing of regulations and industry response. Such research should consider the industry response not from a static economic perspective, but from the perspective of the strategic games that are played by firms and by regulators.

6.2 Economic Incentive Regulation

The last several years have witnessed a growing interest in the substitution of economic incentives for command and control regulations in circumstances where such incentives as pollution taxes or fees can effectively influence firm behavior to meet social goals. Economic incentives for pollution control might also be created by establishing a market in the right to pollute, as with transferable discharge permits.

The static rationale for these approaches, derived from the theory of externalities, suggests that a tax or effluent fee might be used to internalize the costs of environmental degradation, thus causing firms to reduce those costs by controlling their effluents. The dynamic rationale for the economic incentives approaches is that they provide a continuing incentive for technological improvement. From this perspective, it is not so much a matter of getting the externalities straight as it is of using economic incentives to encourage more rapid and continuing improvement in environmental performance. To date, little research has been done to design optimal strategies for using economic incentives to encourage continuing improvements in pollution control. (Nelson, 1978, and Klein, 1981) Nearly all the existing discussion considers the pros and cons of economic incentives in a static, externalities framework. (Oates and Baumol, 1975; Anderson et al., 1977; Kneese and Schultze, 1975)

From the perspective of the regulatory cost analyst, economic incentive programs would be more difficult to assess than command and control programs. For the latter, the cost analyst can specify with some certainty what the industrial repsonse is likely to be, assuming good faith compliance. The analyst does engineering cost analysis for existing technologies, perhaps modified by whatever he is able to judge about the dynamics of learning and innovation.

On the other hand, for economic incentives one must first estimate what the response of the regulated industry might be to, for example, an effluent fee, a marketable permit system, or a pollution tax. This requires not only an estimate of the cost of achieving a particular level of control, but also an estimate of the costs of a range of levels of control as the basis for generating a supply curve for environmental control. The analyst must then identify the technologies and performance levels for which the marginal costs of control are just equal to the marginal savings from avoiding the pollution fee for each real or model plant. Fortunately, the analyst can assume that an effluent fee or pollution tax sets an upper bound on the cost of regulation to industry, since no rational firm would control its effluents to a level that would cost more than paying the fee. However, other more complex economic incentive approaches such as marketable permits or auction systems provide serious conceptual and practical difficulties for the regulatory analyst, since he can no longer fall back on the size of the effluent fee or tax to establish the maximum cost of compliance. The analytic problems with these approaches, which derive from their virtue that they encourage a diverse response, may effectively preclude systematic decisionmaking based on formal cost/benefit analysis for such purposes as setting emission fees, determining the initial price of transferable discharge permits, or determining the optimal numbers of such permits to be issued. (The latter problem would remain, even if the permits were initially auctioned.)

These observations suggest that the choice between command and control and economic incentive regulations by the legislature may reflect the legislators' preferences for the allocation of uncertainty. For example, for an effluent fee approach one is very uncertain about the proper fee, the technological response, and the benefits of pollution control; but the fee sets a known limit on the regulation's cost and makes enforcement using the tax collection system relatively straightforward. By contrast, a performance standard offers less technological uncertainty and greater certainty of achieving a particular level of control, but offers great uncertainty about compliance costs and makes enforcement complex. Also, as noted by Kneese and Schultz (1975), there are circumstances in which equities and technical realities limit the application of the economic incentive approach. Mixed approaches may offer the best balance of achieving environmental goals and controlling regulatory costs. These include such tools as bubbles, offsets, and noncompliance penalties pegged to cost savings or benefits foregone. While these offer the potential for technological improvement, no empirical research has yet been done to evaluate the impact on innovation of the mixed approaches that are curently being tried.

7.0 Findings and Conclusion

7.1 Regulatory Cost Analysis

In view of the statutory and Presidential demands for basing regulatory decisions on analyses of their costs and benefits, it is imperative that their costs and benefits be assessed accurately and fairly.

Currently, the costs of proposed regulations are assessed using methods of cost engineering that have been developed for entirely different purposes. These methods are not appropriate for regulatory analysis. Their use causes a systematic overstatement of the ex ante costs of regulatory proposals.

Cost engineering has evolved as a method for guiding individual firms in making private investment decisions about technologies with performance parameters and design characteristics that are well known or that can be projected within reasonable limits. Cost engineering is inherently a static mode of analysis that does not account for change.

Environmental regulation, on the other hand, is intended to cause firms in an industry to change the technologies they use so as to control the risks they pose to human health and environmental quality. Assessing the costs of making such changes inherently requires a dynamic mode of analysis that can account for change.

The regulatory analyst and the regulatory decisionmaker are likely to be most certain about the costs of the least-creative and highest-cost environmental controls, and are likely to be least certain about the costs of the most-creative and lowest-cost approaches. Until considerable additional research is done to compare ex ante and ex post estimates of the costs of regulatory compliance, it is unlikely that there will be any basis for estimating the impacts of learning and of innovation on compliance costs in a rational way. To the extent that regulatory decisions are based on cost/benefit analysis, currently-used methods of cost analysis will lead to inadequate control of environmental hazards.

7.2 Research Needs

Despite a decade of theoretical analysis, case studies, and modeling efforts, there is surprisingly little systematic understanding of how technological change and the learning curve phenomenon influence the costs of firms' adaptation to a changed economic or regulatory environment. The regulatory analyst, faced with the practical problem of advising a regulatory decisionmaker about the economic consequences of a proposal, has nowhere to turn for guidance in doing proper analyses other than the fragmentary anecdotal literature of the type reviewed in this paper. If static engineering cost analyses are inadequate and inaccurate, can they be brought into line by applying a "correction factor" that varies in a systematic way with characteristics of the regulated industry, its markets, its technology, and the design of the regulation? Or, is some entirely different mode of forecasting more likely to be useful?

Since regulatory analysis is now firmly established as a policy, if not in concept or detail, there is an urgent need to learn how better to analyze and project regulation's consequences, both its costs and its benefits. Interestingly, both the costs and the benefits depend critically on the nature of the industrial response to regulatory requirements, both in terms of compliance behavior and in terms of the technologies that are developed and adopted to achieve compliance.

This paper has identified a number of research areas that are worthy of further study, not only for the immediate purpose of improving regulatory cost analysis, but also to improve the design of regulation and to enhance our understanding of the technological response of industry to all types of changes in its environment, including regulation. The following topics stand out as research needs:

1. Extend existing models of the impact of regulation on technological innovation, based on behavioral theories of dynamic response.

2. Document and analyze the responses of a variety of industries and firms to regulatory requirements, with emphasis on the nature, sources, and costs of compliance technologies; on cost reductions due to learning and innovation; and on organizational and strategic change.

3. Compare and contrast ex ante estimates of compliance costs with the ex post findings of carefully conducted case studies, at a level of disaggregation that would allow for testing a model that takes into account the nature of the regulated technology, the structure of the industry, the severity of the problem, and the details of the regulatory stimulus.

4. Use the results of studies of type 1, 2 and 3 to develop or improve methods of ex ante engineering cost analysis that account for learning and innovation in a reasonable way.

5. Develop a data base and models that can be used to forecast regulatory compliance levels under various circumstances.

6. Do case studies to build a data base on the effects of the institutional and design aspects of command and control regulations on the technological responses of firms to regulation.

7. Expore the possibility of fundamental new approaches to environmental regulation that create strong incentives for reducing both hazards and compliance costs. While economic incentives may be one such approach, they need further study and experimentation to determine how best to structure them. Combinations of regulatory sanctions and incentives such as noncompliance fees, "bubbles," and offsets should also be considered further.

It is important that studies in these area involve several disciplines, including engineers, economists, cost engineers, behaviorists, and regulatory specialists. Traditional static economics and traditional cost engineering have not adequately addressed the issues raised in this paper, and they are unlikely to do so alone in the future. Thus, interdisciplinary research should be encouraged.

It is not appropriate to recommend a prioritization of the research topics listed above--instead, a mix of activities is needed. Three blocks of activities appear to make up a coherent program that attacks the immediate need for better regulatory analysis, while providing the basis for long-term improvements in regulatory design and analysis. For example, topic (4) studies should begin at once, though topics (2) and (3) are logical percursors to (4), and topic (1) to topics (2) and (3). I would recommend, however, that one block of resources be devoted to "fundamental" studies on topics (1) and (7) together; another block to "applied" studies on topics (2), (3), and (4); and another block to "applied" studies on topics (5) and (6). Allocation of research monies to such blocks at a high level would avoid the tendency of short-term projects to crowd out long-term, more risky and fundamental projects when they must complete one-on-one for support.

Finally, it is important to note that a similar, if not longer list could be created for research needs and opportunities on regulatory effectiveness and benefits assessment. These are equally worthy of research support.

The analysis of technological change, or "dynamic economics," unlike static economics and classical physics, is guided by neither a maximizing principle nor a conservation law. As in many other fields that study growth and change, students of technological innovation must depend on heuristics and extensions of static concepts to guide their work. Perhaps a "non-equilibrium economics" will emerge to play the same role in guiding economic thought beyond statics as has non-equilibrium thermodynamics in guiding thermodynamics into the realm of change. In the meantime, the fact that studies of change are challenging and uncertain does not mean that change can legitimately be ignored, even in the relatively narrow field of regulatory analysis. For to ignore dynamics in human affairs is to ignore that which distinguishes us from the rest of nature--the ability to consciously change in response to our surroundings and to each other.

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ESTIMATING ENVIRONMENTAL COMPLIANCE COSTS FOR INDUSTRY: ENGINEERING AND ECONOMIC APPROACHES

by

Raymond J. Kopp
and
Paul R. Portney
Resources for the Future, Inc.
Washington, D.C.

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1.0 Introduction

The U.S. economy has changed in a number of ways over the last 10 years. One of the important changes has been the extent to which certain kinds of activities have come to be circumscribed by Federal regulations. These regulations extend from limitations on the discharge of air and water pollutants and permissible concentrations of harmful substances in workplaces to requirements governing the hiring and firing of employees. In both breadth and intensity, Federal regulation has become more pronounced.

But how much more pronounced? This is a difficult question to answer because we often do not know how much regulation costs affected individuals, firms, and governmental units. These costs of regulation are one--but certainly not the only--important measure of the scope and impact of regulation on the economy. One reason we lack such a measure of the cost of Federal regulation is that the expenditures necessitated by regulation do not pass through the Federal budget. That is, EPA does not install flue gas scrubbers on electric power plants or build cooling towers at these facilities to ease thermal water pollution. Rather, they require these expenditures of private firms and there is very little Federal accounting of the expenditures made by regulatees, either public or private.

This paper is concerned with the estimation of the costs incurred by the private sector in complying with Federal environmental regulation. Its purpose is not to develop new estimates of these costs or to critique in great detail existing methodologies. Rather, our primary purpose is to discuss briefly the pros and cons of existing approaches to compliance cost estimation, outline several new and more comprehensive methodologies, and discuss the problems that would be encountered in trying to put these approaches into practice.

In Section II we indicate several reasons why compliance cost information is important, and draw several semantic distinctions it is important to bear in mind when thinking about such costs. Following that, we discuss a number of ongoing attempts to estimate the expenditures in previous years on environmental regulation; we also discuss several new ways in which inferences can be drawn about prior pollution control spending. Next, in Section II, we take up the ex ante estimation of industrial compliance costs. That is, we look at ways in which prospective rather than existing regulations can

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*Raymond J. Kopp is Fellow, Quality of the Environment Division, Resources for the Future (RFF), and Visiting Assistant Professor of Economics, University of North Carolina. Paul R. Portney is Senior Fellow, Quality of the Environment Division, RFF. The authors wish to acknowledge the very helpful comments of Margaret Slade and William Vaughan on an earlier draft of this paper. Jeff Kolb of the Environmental Protection Agency (EPA) graciously made available the data on use of tax-exempt pollution control bonds, which facilitated our analysis. Kopp acknowledges the support of the Andrew W. Mellon Foundation in conjunction with this work.

be expected to affect the private sector. In Section IV we discuss the current method of forecasting compliance costs (which we refer to as the "input cost accounting approach"), as well as several more sophisticated methodologies to determine these costs, including engineering process models and neoclassical econometric models. A final section, Section V, touches on the practical prospects for improving compliance cost estimation in the ways we have suggested.

2.0 Why Estimate Compliance Costs?

Given the difficulties in identifying and quantifying them, one might question the need for more accurate estimates of environmental compliance costs. There are three reasons it is important to know these costs. First, and most simply, cost-benefit analyses of Federal regulatory programs are impossible without accurate estimates of environmental compliance costs. These cost-benefit analyses are in turn important because, when properly done, they can assist in identifying areas where additional regulation may do more harm than good, and areas where additional regulation will improve the allocation of resources resulting from the unaided private market. Efficiency in the allocation of resources is not the only economic goal of Government, of course. Economic policy is designed to address both macroeconomic stability as well as the distribution of income. Nevertheless, efficiency in resource allocation is one very important goal, arguably the principal reason for the creation of federal regulatory agencies.

Accurate compliance cost estimates can do more than contribute to sound benefit-cost analysis, however. They can also be used to make inferences about the macroeconomic consequences associated with environmental regulation.[1] That is, compliance cost estimates can be used in a number of ways to help determine the effects of regulation on the price level, the unemployment rate, the rate of economic growth, the balance of trade, the levels of investment and productivity, and other indicators of aggregate economic activity. Thus, compliance cost estimates are essential to understanding both the allocative as well as the cylical or countercyclical effects of environmental regulation.

Finally, accurate estimates of environmental compliance costs are essential if the costs imposed by regulatory agencies are ever to be subject to the same kinds of controls imposed on the direct spending of the various departments of the Federal (and other levels of) Government. To elaborate, some students of regulation have proposed that EPA and other regulatory agencies be subjected to a "regulatory budget" that would limit the annual total expenditures each could require public and private regulatees to make (in much the same way each of these agencies is currently limited in what it can spend for salaries, rent, travel, consultants, and so forth).[2] Since no limit now exists, some critics of regulation argue, agencies have no incentive to limit their regulatory appetites and establish priorities among and within programs--in short, they have no incentive to think about new regulations in a way that is useful to society.

But if such a regulatory budget were ever to be considered seriously, one thig is clear: It would fail if there were no way to assess with some confidence the costs that regulated parties were forced to bear as a result of agencies' regulations. For it is only by adding up these costs that one could determine whether or not an agency had exceeded its regulatory budget for the year. Unlike the direct expenditure budget, there are no cancelled checks that can be tallied at the end of the year to check on total, on-budget spending. Without an accounting system maintained by the regulatory agencies, an oversight body, and/or regulatees themselves, such an accounting would be impossible and the regulatory budget virtually unenforceable.

Thus, for a number of reasons it is important to have accurate information about the costs of complying with environmental regulation. Not only is such information essential to the analysis of the allocative, distributive, and macroeconomic effects of regulation; it is also a precondition for any type of new mechanism to control the costs that regulatory agencies impose on private and public parties.

Before turning to ways these costs have been examined in the past, it is useful to discuss briefly the kinds of compliance costs referred to throughout this paper.[3] The concept of costs appropriate to a benefit-cost analysis of environmental regulations is of course social opportunity cost. That is, all the productive opportunities that are foregone throughout the economy as a result of a regulation (not just those foregone by the regulatee) must be included as costs of the regulation. These will generally be greater than, but may sometimes be less than, the expenditures made by firms in response to regulation.[4] Nevertheless, for the purposes of this paper the terms "pollution control expenditures," "pollution control costs," and "compliance costs" will be used more or less interchangeably.

We also distinguish in this paper between direct and indirect costs. By the former we mean those associated with regulation that would show up in an accounting statement--purchases of capital equipment, expenditures for the materials and energy to run the equipment, labor to operate and maintain it, and resources devoted to the recordkeeping and other administrative requirements arising from regulation. Indirect costs are also very important consequences of environmental and other regulation, but generally do not show up in the same way as direct costs. They include: (1) the diminished productivity that may result when regulations are imposed on private firms; (2) the reduction in innovative activity perhaps induced by regulation; and (3) the losses that result when regulation induces "upstream" or "downstream" changes in factor mixes that inhibit production, etc.

None of these kinds of effects will appear on a balance sheet across from an entry indicating a regulatory requirement. Nonetheless, they are very important, so important, in fact, that one of us has argued that econmetric simulations of the effect of regulation on the economy cannot be taken too seriously for the very reason that they exclude these indirect costs.[5] It is because of the importance of these costs that we suggest in a later section the use of more complicated models to determine compliance costs than have been used in the past.

3.0 Ex Post Estimates of Environmental Compliance Costs

The most important use of compliance cost estimates is probably to determine, in advance of regulation, what would be the allocative and macroeconomic effects of the proposed rule. Nevertheless, we begin with a discussion of ex post estimates of the costs of complying with existing rules and regulations. There are a number of ways of determining past compliance costs; the problems encountered in these approaches foreshadow the difficulties that will arise in estimating the expected costs of proposed rules. Most of the ex post estimates are made using surveys of affected firms.

3.1 Survey Estimates of Expenditures[6]

Considering their importance, there are surprisingly few comprehensive estimates available of past expenditures for pollution control. Sometimes the information that is available is conflicting or disparate. For example, both the Bureau of Economic Analysis (BEA) and the Bureau of Census within the Department of Commerce conduct annual surveys to determine expenditures on pollution control. Similarly, McGraw-Hill, Incorporated also surveys business annually to determine pollution abatement expenditures. Table 1 compares estimates from these three sources of actual capital investment in pollution abatement control for 1978, and estimates from McGraw-Hill and BEA of planned capital expenditures for 1980.

Table 1. Estimatated Capital Expenditures for Pollution Control
(millions of dollars)

	1978 ACTUAL			1980 PLANNED	
Industry	(1) McG-Hill[a]	(2) BEA[b]	(3) Census[c]	(4) McG-Hill[d]	(5) BEA[b]
Iron and steel	425	441	{793	1,069	638
Nonferrous metals	293	247		285	285
Other primary metals	-	54		-	87
Electric machinery	134	130	75	238	126
Machinery	243	111	82	196	97
Autos, trucks, parts	193	198	{140	162	311
Aerospace	45	23		30	34
Fabricated metals	137	-		189	-
Instruments	58	-		146	-
Stone	207	164	127	125	176
Other durables	190	181	186	116	199
Total durables	1,935	1,561	1,402	2,559	1,956
Chemicals	547	565	842	762	476
Paper/Pulp	274	239	342	473	300
Rubber	100	58	28	201	58
Petroleum	834	1,294	420	1,525	1,536
Food/Beverage	309	172	185	181	150
Textiles	81	29	60	110	36
Other nondurables	67	32	37	97	27
Total nondurables	2,212	2,389	1,914	3,450	2,583
Total manufacturing	4,147	3,950	3,316	6,009	4,540
Mining	511	206		109	171
Railroads	54	36		53	32
Airlines	20	15		97	13
Electric utilities	2,791	2,472		3,615	2,558
Gas utilties	60	35		61	44
Commercial	{423	{220		512	{243
Commercial & other trans.				93	
	3,859	2,974		4,539	3,161
ALL BUSINESS	8,006	6,924		10,548	7,699

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[a] 12th Annual McGraw-Hill Survey of Pollution Control Expenditures, May 14, 1979.

[b] Gary Rutledge and Betsy O'Connor, "Capital Expenditures by Busines for Pollution Abatement, 1978, 1979, and Planned 1980," Survey of Current Business, June 1980.

[c] Pollution Abatement Costs and Expenditures, 1978, U.S. Bureau of the Census, MA-200(78)-2, U.S. G.P.O., Washington, D.C., 1980.

[d] 13th Annual McGraw-Hill Survey.

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As columns 1, 2, and 3 of the table indicate, there are considerable differences among estimates, even with respect to actual or historical capital expenditures. For example, McGraw-Hill's estimate of pollution control investment in the machinery industry in 1978 is three times that of the Census Bureau, and more than twice that of BEA. On the other hand, the Census estimate for investment in pollution control by the chemical industry is about 50 percent greater than the estimates of either McGraw-Hill or BEA. BEA's estimate for petroleum refining is more than three times that of the Census Bureau, and is 50 percent higher than McGraw-Hill's reported total. Other differences in both individual industry and total estimates are clear.

Given the discrepancies among estimates of historical expenditures for pollution abatement capital, one might expect even more divergent estimates of planned future expenditures. Columns 4 and 5 of table 1 confirm this suspicion. According to McGraw-Hill, total planned capital expenditures for pollution abatement for all business in 1980 were $10.5 billion. This was 37 percent more than BEA projected based on its survey of manufacturing and nonmanufacturing firms. For the electric utility industry alone, the McGraw-Hill and BEA estimates of 1980 investment in pollution control differed by nearly a billion dollars.

There are two major reasons why these three sets of estimates diverge so. First, the Census Bureau surveys establishments or plants, while the BEA survey goes to firms. Hence, if a multidivision firm has operations in several different industries, all of its pollution control expenditures across all operations are attributed by BEA to its primary product. Thus, expenditures for pollution control in U.S. steel's paintmaking operations are recorded under "steel works" in the BEA survey. This accounts for some of the difference between BEA and Census. Second, the sample sizes used by BEA, Census, and McGraw-Hill differ. The Census Bureau surveys 20,000 plants to estimate pollution control investment in the manfuacturing sector. The Bureau of Economic Analysis surveys about 15,000 firms to prepare its estimate. McGraw-Hill, like BEA, bases its estimates on a sample of firms, yet they sample only 346--less than 3 percent of BEA's sample size. Hence, all three sources are trying to estimate national totals based on different sample sizes, composition, and definitions.

Several factors point toward possible upward bias of all three sets of estimates. Although the response rates for the McGraw-Hill and Census surveys are unknown, it is about 60 percent for BEA, of which at least some responses no doubt prove unusable. It is not unreasonable to expect that the firms that do respond to the survey are those that are spending considerable amounts on pollution abatement. If their experience is generalized to all firms in an industry, the resulting estimates will be high. This will be particularly true in industries with both large firms and small firms. Since many regulations exempt firms below a certain size, the effect of environmental rules on all small firms taken could be negligible. Yet, if a number of small firms are treated as one big firm, estimates of their expenditures may be large.

Second, some respondents can be expected to have difficulty determining which portion of capital and operating expenditures is due to pollution abatement and which portion is made to improve normal operations and increase profitability. This joint cost problem is especially difficult when new facilities are constructed or existing ones are modified. The temptation in such cases is to err in the direction of large pollution control expenditures, creating a possible further upward bias to the estimates. Finally, although there is little evidence to support such a supposition, some firms may deliberately report erroneously high numbers in an attempt to cast regulation in a bad light.

There is another problem with the BEA, Census Bureau, and McGraw-Hill estimates. Not only are they of questionable value in estimating what they attempt to estimate, but that which they do estimate may not be what we are after. This is because the totals reported in the three surveys discussed above encompass pollution control spending that arises not only as a result of Federal environmental regulation, but also spending necessitated by State and local controls, and spending voluntarily undertaken (as for good will). In terms of the distinction drawn by the Council on Environmental Quality (CEQ), the surveys discussed above report total pollution control spending but do not separate out incremental spending (due to Federal regulation). This extends not only to estimates of annual capital expenditures but also to estimates of annual operating costs.

The Census Bureau does try to eliminate one type of pollution control spending from their totals--that which results in the profitable recovery of byproducts. Their survey makes allowance for and deducts this offsetting revenue (see Item 5 in the survey and its explanation in the "specific instruction"). Nevertheless, even the Census Bureau survey lumps together pollution control expenditures made in response to local, State or Federal regulations and those expenditures made for good will. Thus, neither it nor the BEA or McGraw-Hill surveys are particularly useful in identifying pollution control costs that arise exclusively as a result of Federal environmental regulation.

Even if the three surveys did isolate expenditures made in response to Federal regulation, they would not be ideal for the tasks at hand. This is because the surveys lump together all air pollution spending, all water pollution spending, and all spending on solid waste. That is, there is no way to differentiate the effect of air pollution controls in State Implementation Plans, for example, from those arising from new source performance standards, or from controls to prevent emissions into the atmosphere of hazardous air pollutants. Although survey estimates of aggregate spending necessitated by Federal regulation would facilitate macroeconomic analysis, they would still not be useful in evaluating the allocative effects of specific regulations. For this, estimates would be needed on a regulation-by-regulation basis. It is unlikely that large-scale surveys of the sort discussed here will ever provide such detailed information.

Even when firms have been surveyed in considerably more detail, this latter problem has remained. The analysis performed by Arthur Andersen and Company for the Business Roundtable (AA/BR) is a case in point.[7] This study was billed as the most comprehensive analysis to date of the economic effects of Federal regulation on 48 major U.S. corporations. It included not only environmental regulation, but also occupational safety and health controls, affirmative action requirements, energy regulations, Federal pension and retirement restrictions, and consumer protection requirements mandated by the Federal Trade Commission.

Perhaps the most significant aspect of the AA/BR study is the methodology it employed. A conscious effort was made to isolate for the year in question, 1977, those expenditures that arose solely as a result of Federal regulation. According to AA/BR, for example, the study excluded air and water pollution control expenditures that the reporting firms would have made even had these expenditures not been required by regulation. This should make their estimates very conservative. For instance, suppose no law prohibited the discharge of substance X into the air. A law is then passed which prohibits this discharge. One would assume that any costs associated with the control of X would be counted as incremental control costs. Not so in the AA/BR study. If a firm was controlling substance X to some degree prior to regulation, those costs are netted out of total control costs in calculating the incremental cost of complying with the regulation. (Figure 1 on p. 103 illustrates the AA/BR methodology).

There are several observations to be made about the AA/BR approach. First, it does improve in a couple of ways on the survey approach taken by BEA and the Census Bureau. Not only are incremental costs distinguished from other pollution control expenditures; also, it is somewhat easier to link incremental costs to specific regulatory requirements. For instance, the report targets particulate removal under State Implementation Plans as being expensive (especially in relation to the amount removed). It also identifies the national ambient air quality standard for ozone as being expensive for the firms surveyed to comply with.[8]

Second, the AA/BR study is bedeviled by a problem that always crops up in attempts to isolate regulation-induced spending from that which would take place anyway. This problem arises because it is always difficult if not impossible to determine what a firm would have spent in the absence of a particular regulation. Since this varies from firm to firm--some would voluntarily remove much more pollution than others, for instance--it is very difficult to extrapolate from a simple sample of firms (48 in the AA/BR study) to the economy as a whole. For this reason and several others, no economy-wide estimates of regulatory burdens in 1977 were hazarded by AA/BR.

While understandable, this failure to generalize the findings from the 48 firms involved to the whole economy limits the usefulness of the AA/BR study. It makes it impossible, for example, to compare the BEA, Census Bureau, and McGraw-Hill estimates of new investment in pollution control with the figures in the AA/BR study. This is unfortunate because of the careful and conscious focus in the latter on incremental effects. This in turn makes it difficult to use the AA/BR study as a basis for any analysis of the macroeconomic effects of regulation on the economy.

What can we conclude about the use of surveys to make inferences about pollution control expenditures? Two observations seem warranted. First, while they provide some useful information, the BEA, Census, and McGraw-Hill surveys will not be useful either for micro- or macroeconomic analyses until they distinguish between expenditures necessitated by Federal regulation and those arising for other reasons. Second, since all the surveys are based on extrapolations from a sample of firms or establishments to the industry as a whole, it is important to treat the overall estimates cautiously. In fact, the problems of extrapolation were so great with the AA/BR study that no attempt was made to generalize the findings from the 48 firms involved to the economy as a whole. Some of the same problems exist with the other three surveys, of course. Finally, we should remember that even perfect surveys will give us information only about past expenditures for environmental quality management. Useful as this information may be, it does not help in ex ante analyses of regulatory impacts.

3.2 Other Checks on Pollution Control Spending

One disadvantage to all survey approaches is that they rely on firms for accurate information on pollution control spending. When firms misunderstand survey instruments, when samples are unrepresentative of the entire population, or when firms strategically mis-state true spending, economy-wide estimates of pollution control spending based on surveys may be misleading. In this section we discuss briefly two means which might be used to check on the accuracy of firms' reported estimates of pollution control spending.

As a result of the Revenue and Expenditure Control Act of 1968, the use of tax-exempt industrial development bonds (IDBs) was sharply curtailed. One use of these bonds for which their tax-exempt status could be retained was for investment in pollution control equipment. These IDBs are issued by quasi-public agencies and the proceeds of the bond sale are used by private firms to install end-of-pipe pollution control equipment.[9] The firm repays the bond holders in much the same way it would if it floated the bonds privately. Since fairly good statistics are kept on the size and composition of the market for tax-exempt pollution control bonds, it is possible to compare survey estimates of pollution control spending with actual data on the use of tax-free bonds. Tables 2-4 compare estimates based on the BEA survey of capital investment for pollution control from 1975 to 1980 with data on the actual use of IDBs on both an aggregate and industry basis.

Several interesting observations can be drawn from the tables. First, even after eliminating investment in the process change--which does not qualify for tax-exempt financing--IDBs have only been used for 43 percent of all BEA-estimated investment in end-of-pipe pollution control since 1975. In 1980, only 39 percent of end-of-pipe investment in pollution control was financed with tax-exempt IDBs. In addition, according to BEA surveys, although new investment in end-of-pipe control equipment rose every year but one from 1975 to 1980, the volume in the tax-exempt market has fallen in four of those years, the last three consecutively. Although the total number of issues has risen slightly for the last two years it is still below its level in 1975, and considerably below 1977 when 221 new tax exempt issues were brought to the market.

Equally interesting are the figures on individual industry use of IDBs. As table 3 shows, certain industries rely to a much greater extent than others

Table 2.

		1975	1976	1977	1978	1979	1980	Total
1.	Total Volume of Tax Exempt Pollution Control Bonds ($$10^6$)	2,134	2,056	2,982	2,793	2,466	2,463	14,894
2.	Number of Issues	193	168	221	155	163	170	1,070
3.	Average Issue Size ($$10^6$)	11.1	12.2	13.6	18.0	15.1	14.5	13.9
4.	New Investment in Pollution Control Plant and Equipment	6,549	6,762	6,939	6,924	7,143	7,699P	42,016
5.	New Investment in End-of-Pipe Plant and Equipment (Including solid waste)	5,419	5,524	5,609	5,549	5,826	6,376P	34,301
6.	Total capital expenditures (corporate)	113,489	121,232	137,017	153,090	176,371	195,673P	896,872
7.	IDBs as a percent of end-of-line pollution control expenditures	39.4	37.2	53.2	50.3	42.3	38.6	43.4
8.	IDBs as a percent of total capital expenditures	1.9	1.7	2.2	1.8	1.4	1.3	1.7
9.	Total Tax Exempt Financing (adjusted by CBO study on IRBs)	30,126	34,914	46,860	49,115	48,061	53,282	262,358
10.	Corporate Bonds	42,756	42,380	42,015	36,872	40,139		
11.	IDBs as a percentage of tax exempt financing	7.1	5.9	6.4	5.7	5.1	4.6	5.7
12.	IDBs as a percentage of corporate bonds	5.0	4.9	7.1	7.6	6.1		

Sources: Lines (1) - (3): Weekly Bond Buyer, Jan. 26, 1976, Jan. 31, 1977, Jan 23, 1978, Jan 22, 1979, Jan. 21, 1980, and Jan. 19, 1981.
Lines (4) - (6): Survey of Current Business, June 1978 and June 1980.
Line (9): Weekly Bond Buyer, Jan. 8, 1979 and Jan. 12, 1981; Small Issue Industrial Review Bonds, CBO, April 1981, p. 14.
Line (10): Federal Reserve Bulletin, April 1979, December 1980.

Table 3.

	1975	1976	1977	1978	1979	1980^{P}	Total
			(Millions of dollars)				
Pollution control cost--capital expenditures for end-of-line methods plus solid waste							
Electric Utilities	1336	1735	1907	1932	2183	2264	11,357
Petroleum	963	932	859	1027	1150	1296	6,227
Metal processors	889	799	791	622	724	892	4,717
Chemicals	561	577	544	476	387	398	2,943
Paper	463	411	364	215	260	234	1,947
All Other	1205	1070	1144	1277	1122	1292	7,110
Total	5,417	5,524	5,609	5,549	5,836	6,376	34,301
IDB Financing							
Electric Utilities	628	1027	1919	1558	1579	1429	8,140
Petroleum	220	261	142	83	59	117	882
Metal Processors	529	276	373	647	246	263	2,334
Chemicals	253	208	244	189	181	137	1,212
Paper	224	121	155	98	141	159	928
All Other	280	163	149	218	260	328	1,398
Total	2,134	2,056	2,982	2,793	2,466	2,463	14,894
IDB Financing as a Percent of Pollution Control Costs							
Electric Utilities	47.0%	59.2%	100.0%	80.6%	72.3%	63.1%	71.7%
Petroleum	22.8	28.0	16.5	5.1	5.1	9.0	14.2
Metal Processors	59.5	34.5	47.2	104.0	34.0	29.5	49.5
Chemicals	45.1	36.0	44.9	39.7	46.8	34.4	41.2
Paper	48.4	29.4	42.6	45.1	54.2	80.8	47.7
All Other	23.2	15.2	13.0	17.1	23.2	25.4	19.7
Total	39.4%	37.2%	53.2%	50.3%	42.3%	38.6%	43.4%

Table 4. Total Use of IDBs and Percent Distribution of Use by Industry Type (1975-80)

	Total IDBs Used ($ million)	Percent Distribution (%)
Electric Utilities	$8,140	54.7%
Petroleum	882	5.9
Metal Processor	2,334	15.7
Chemicals	1,212	8.1
Paper	928	6.2
All Other	1,398	9.4
TOTAL	$14,894	100.0%

on tax-exempt financing. For instance, during 1975-80, the electric utility industry financed with IDBs nearly 72 percent of the investment BEA estimated it made in end-of-pipe plant and equipment. By contrast, the petroleum refining industry used IDBs to finance but 14 percent of its pollution control investment. The average for the other industries for which data are available is about 45 percent. In addition, table 4 indicates that the electric utility industry accounted for more than half, 55 percent, of all IDBs issued between 1975 and 1980. This is in spite of the fact that it accounted for less than a third of all investment in end-of-pipe pollution control during this same period according to BEA.

In 1980, the average IDB carried a net interest cost of about 9.5 percent. By contrast, the average yield on long-term corporate bonds issued in 1980 was 13.5 percent. On an average-sized issue of $15 million, this means interest costs are lower by about $0.6 million per year on the tax exempt bonds. In view of the significantly lower interest firms have to pay on tax-exempt bonds, why is it that less than half of all estimated investment in end-of-pipe pollution control in 1980 was financed by IDBs? Could this be a sign that firms exaggerate when responding to the BEA capital expenditure survey? Do the IDB figures give a more accurate picture of investment in pollution control? In spite of the temptation to draw such a conclusion, there are several reasons to believe that tax-exempt bonds would never be used to finance all end-of-pipe investments in pollution control.

First, the tax code restricts the use of IDBs to air and water pollution control--they can not be used to finance investments that will reduce the generation of solid waste. Thus, from line 5 in table 2 would have to be subtracted solid waste expenditures before one could get an accurate picture of actual IDB use relative to maximum possible use. The solid waste expenditures to be deducted, however, are small in comparison to end-of-pipe capital spending for air and water pollution control--in 1980 they amounted to $566 million, or about 9 percent of end-of-pipe spending. Thus, one must look elsewhere to explain the large amount of capital spending on pollution control that does not make use of the tax-exemption for IDBs.

Of course, firms may elect to finance capital expenditures (for pollution control or otherwise) in many different ways. For instance, one reason why the petroleum industry may have relied very little on tax-exempt bonds to finance pollution control (only 14 percent between 1975 and 1980) may have been their favorable profit picture over this period, particularly during 1977-80 when they financed only about 7 percent of pollution control investments with tax-exempt bonds. This may also explain the relatively intensive resort to the IDB market by electric utilities, since they have not done well as a whole over the last 5 years.

Finally, there are other impediments to the use of tax-exempt bonds that limit their use. In some cases, it may simply be that a pollution control investment is too small for a firm to go to the trouble and expense of securing an underwriter for the bonds, helping the authorized pollution control financing agency to put together the package, and marketing the bonds. Rather, it may find it expedient to install the equipment and skip the favorable tax advantage.

In other cases additional limitations on the use of IDBs may reduce their use. For instance, the Internal Revenue Service (IRS) forces firms to deduct from the amount of the investment to be financed the value of any materials that may be recovered in the waste stream, but IRS does not allow the costs of this recovery to be subtracted from this value. Thus, if sulfur will be recovered when a scrubber is installed, the market value of the sulfur must be deducted from the capital cost of the scrubber even though it may not be economic to recover the sulfur from the scrubber sludge. Similarly, IRS requires firms to deduct from the amount of investment to be financed the interest earned on the capital which is saved when bonds rather than retained earnings are used to finance pollution control. In other words, if the assumed rate of interest is 12 percent, IRS automatically reduces the amount that can be financed via IDBS by 12 percent. This provision also has an obvious effect on the volume of tax-exempt financing and drives a wedge between investments that would appear to qualify and those which are actually made using IDBs.

All this is not to deny the possibility that firms knowingly or unknowingly exaggerate investment in pollution control when they respond to the BEA, Census Bureau, McGraw-Hill, or other surveys. They may, and this would explain some of the difference between the BEA estimates and the volume observed in the market for tax-exempt IDBs. Nevertheless, as we have pointed out there are other important reasons why we would never expect all investment in pollution control equipment, or even all qualifying investment, to be financed using tax-exempt IDBs.

The preceding discussion raises an interesting issue. If firms currently have little or no incentive to accurately reveal pollution control expenditures, might they be given one? In other words, could a mechanism be devised that would at least bound the apparent incentive of firms to exaggerate pollution control spending?[10] The final "check" on estimates of pollution expenditures we discuss goes to this point.

To understand this approach it is important to note the potentially conflicting motives which a firm may face. On the one hand it may wish to exaggerate the current and future costs it will incur to comply with environmental regulations. By doing so, the firm may give impetus to efforts to "reform" regulation so as to diminish its burden on the public and private sector. At the same time, this firm may have an incentive to understate to a different group--its stockholders--the compliance costs it will face in the future. If future compliance costs were thought to be large, after all, the firm would not be as good an investment as it would if these future burdens were small.

In fact, upcoming liabilities that may reasonably be expected to result from environmental and other regulations must be identified in the 10K report that each firm must file with the Securitis and Exchange Commission each year. Several prominent firms have been penalized by the SEC for failing to report accurately these liabilities.[11] It is reasonable to inquire, then, whether these 10K reports might provide useful information on pollution control spending. The answer would appear to be that while such reports may be of some use in determining future (or ex ante) compliance costs, they will probably be of little use in determining past spending. It is not their purpose to present information on prior environmental expenditures--this information will be available from the firm in other forms. And the firm would appear to have the same incentive to exaggerate prior environmental spending in reporting to stockholders as it was when responding to surveys.

The SEC reporting requirement might be used in an attempt to create "incentive compatibility" in estimating future costs, however. Suppose a firm were required to report on its 10K filing to the SEC the same estimates of future environmental compliance costs it provides to EPA during the period a proposed regulation is being considered. This might temper somewhat a firm's inclination to exaggerate those expected compliance costs. The larger the estimate they made, the less good the firm would look to current and potential stockholders. While such a consistency requirement has problems of its own,[12] it might help to reduce any exaggeration that currently takes place in responding to surveys on environmental control expeditures. As suggested above, however, such an approach is more relevant to the ex ante estimation of control costs than it is to estimates of spending in previous years. It is to these methods of ex ante cost estimation that we now turn.

4.0 Ex Ante Estimates of Compliance Costs

As we indicated above, it is just as important to have accurate estimates of the expected costs of proposed regulations as it is to know how much is being spent as a result of existing rules. In this section we turn our attention to methods of ex ante estimation of environmental compliance costs. Here we try to do more than discuss the current methods of ex ante estimation, the most important of which we refer to as the "input cost accounting approach." We also discuss in some detail the way that two additional methodologies could be applied fruitfully to the estimation of expected compliance costs. The first methodology involves the use of what are referred to as engineering process models; the second makes use of neoclassical econometric models of the production process.[13]

4.1 The Input Cost Accounting Approach

One way to determine the expected costs of a proposed regulation is to ask the firms, individuals, and governmental units likely to be affected by it. Alternatively, one could rely upon the regulatory agency (EPA in the case of environmental regulation) or its contractors to provide such estimates. Since both regulators and regulatees generally use the same approach to estimate costs (although often with different assumptions), that approach is discussed in some detail here.

As its name implies, the "input cost accounting approach" (or ICAA) consists of two steps. First the estimator determines what additional inputs will be required by the regulation under consideration. Typically those will include capital (as in a flue gas scrubber or electrostatic percipitator), labor (to conduct tests of new chemicals, for instance), natural resources (limestone to inject into flue gases in a scrubber), and energy (which is required to operate all capital-intensive pollution control equipment). Alternatively, if a regulation required a source to burn low- rather than high-sulfur coal, the additional cost of the cleaner coal would be entered as a cost of the regulation. The second stage involves the attribution of costs to these added input requirements, both now and in the future, since at least one concern is with the present discounted value of all future incremental costs attributable to the regulation in question.

Not only must these costs be projected for all existing sources under the ICAA, but a projection must also be made about new sources that eventually will be subject to regulation. In the case of chemical regulation, of course, some estimate must be made of the number of new chemicals that will be introduced and hence subjected to premanufacturing notification and testing. The number of chemicals making it through the process times the cost per chemical would provide an estimate of the increased direct input costs arising from certain chemical regulations.

In some cases--typically in EPA cost estimates--a "model plant" approach is followed. That is, rather than attempt to estimate what will be required in the way of additional inputs at each existing facility by some proposed regulation, one or more model plants are selected which are taken to be representative of other plants in an industry. The ICAA is then used to determine compliance costs at this plant(s), and this cost is then multiplied by the number of average or model plants in the industry to arrive at total incremental cost. While this saves time and money during the cost estimation stage, it can easily create other problems.

The most obvious of these problems comes in determining what is a model plant. This choice has in the past led to both under- and overestimation of actual compliance costs. In some cases, the model plant has been taken to be one of the most modern and advanced in the industry. It is occasionally the case, in fact, that this plant will have already installed some pollution control equipment prior to regulation. This means that additional input requirements at this facility may be small; however, to generalize these small additional incremental costs to other plants in the industry where "pro bono" or anticipatory pollution control has not taken place can lead to substantial underestimates of actual compliance costs.

On the other hand, the model plant variant of the ICAA can lead to over-estimates of compliance costs as well. This can result from the same circumstances described above. For in that case, the pollution control equipment installed prior to the regulation should not be counted among the incremental costs attributable to regulation. Only the additional costs, if any, of meeting the regulation are relevant here. Yet in the case of certain industry responses to the BPT effluent guidelines EPA apparently included in their cost estimates even the equipment that had been installed prior to the regulations. That clearly leads to an overestimate of true environmental compliance costs.

There are other problems with the ICAA as well. Even though an attempt is often made to foresee new technological advances in pollution control, this foresight can never be perfect. Hence, when a new innovation makes pollution control less expensive, actual compliance costs will fall relative to the original estimates. For example, some now believe that fluidized-bed combustion now has or soon will have the ability to lower considerably the costs of sulfur removal from coal-fired industrial and utility boilers. If so, the estimates of the costs of meeting the performance standards for new sources which EPA established in 1979 may be exaggerated.

In addition to technological innovation, compliance cost estimates may exceed actual costs because of what one of us has elsewhere called regulatory innovation.[14] These regulatory innovations are best exemplified by EPA's so-called "bubble" and "offset" policies under which one source of pollution in a plant or area can increase its pollution provided that another source makes an equivalent or greater reduction in its discharges of that same pollutant. Such regulatory innovations are significant because they enable polluters to meet given discharge goals in the least expensive way possible. This means that compliance cost estimates based on cleanup at all sources will exaggerate true costs so long as sources can "buy up" equivalent reductions elsewhere at less expense. Thus, these kinds of flexibility-enhancing reforms will reduce compliance cost estimates based on the ICAA.

A final difficulty with the ICAA is the open-endedness of some of the regulations for which cost estimates must be made. Consider the example mentioned above of new source performance standards for coal-fired utilities. After it was decided how much the new standards would cost a "typical" plant, it was also necessary to estimate how many new plants would be built. Yet this is no simple matter. First, this depends on the rate of growth (or decline) of demand for electricity, something which the utilities themselves have proved to be less than prescient in estimating. Not only are tastes and prices variant, but estimating future demand is also difficult because the rate of adoption of energy conservation practices and alternative sources of energy is difficult to foresee.

Moreover, the number of new plants is not only dependent on exogenous factors like those below. It may also depend to some extent on the very regulations being analyzed. That is, if environmental controls on new plants are significantly more stringent than those on existing sources, new plants may cost so much more that there are fewer of them. Thus new source controls may affect both cost-per-plant and the number of plants. While important, this effect is very difficult to estimate because we cannot observe the plant construction activity that would take place in the absence of new source controls.

For all these reasons, then, the ICAA is flawed. It is understandable as a first order response to the new task of compliance cost estimation, and will continue to be used for quick approximations of compliance costs. But its obvious and subtle limitations point toward the need for a more sophisticated method of estimating compliance. Ideally, such a method would not only provide information about direct compliance costs--that is, additional labor, capital, natural resources, and energy--but would also make possible the identification of at least certain of the indirect costs, as well. These latter costs may include changes in the optimal use of factors both upstream and downstream from the point at which regulations have their initial impact.

The two approaches we discuss next, in more technical detail than in the discussion so far, have the characteristic that they can shed some light on both the direct and indirect costs of regulation. Each of these approaches employs well established modeling methodologies to examine the impact of Federal regulation on production activities. The first approach relies exclusively on engineering data and the physical laws of energy and material transformation. The second approach is founded on the neoclassical-economic theory of the firm and employs this theory in conjunction with economic data and econometric techniques to analyze characteristics of production activities. Neither of these approaches has been extensively employed to examine compliance cost; however, in the following sections we show how these approaches can be developed into useful compliance cost tools, potentially superior to those previously discussed.

4.2 Engineering Process Models

4.2.1 Overview of the Model

The engineering process model is a strictly engineering approach to modeling a production activity, and the impact upon that activity which a proposed environmental regulation can have.[15] As the name implies, this approach decomposes a specific production activity (such as the production of iron and steel) into identifiable engineering processes--each process associated with a specific, well-defined task. Normally, each task can be accomplished by a variety of process configurations which are differentiated on the basis of inputs and the engineering efficiency of the process. The process modeler first determines the sequence of tasks to be performed as required by a particular production activity, and then assembles the alternative processes capable of accomplishing each task. Naturally, the output of one task becomes the input of a succeeding task; thus, internal consistency among the process alternatives must be maintained to insure that a fully specified configuration of process alternatives is capable of accomplishing the overall production activity.

The set of interrelated process alternatives depicts the menu of blueprints from which the complete production activity is assembled. We shall term this set of blueprints the technology for a specific production activity. We define the set of all potential inputs to the technology by the vector x and all outputs by the vector y; we then define the technology as the set of feasible input and output combinations. Formally, we define the technology set T as:

$$T = \{(x,y) \,/\, (x,y) \text{ is a feasible production choice}\} \qquad (1)$$

Once the technology set is established, the process modeler chooses an optimization rule which serves to identify that set of process alternatives, drawn from the technology set T, which optimizes a specific objective function. For example, if the optimization rule was the minimization of total factor cost, subject to the constraint that a given level of outputs be produced, then the process alternatives chosen, combined with the scale of production, would determine the optimal demands for factors of production and the unit cost of producing the specified level of outputs. Formally, the optimization problem appears as (2).[16]

$$\underset{x}{\text{Minimize:}} \quad p'x \qquad (2)$$

$$\text{S.T.} \quad y \geq y^0$$

$$(x,y) \,\varepsilon\, T(x,y)$$

$$p \geq 0$$

where: p = the vector of input prices

y^0 = specified level of outputs

$'$ = vector transposition

and: $y \geq y^0$ requires a given level of output to be produced

$(x,y) \,\varepsilon\, T(x,y)$ constrains the optimal set of process alternatives to be contained (elements of) within the established technology

$p \geq 0$ requires input prices to be nonnegative

If the process model depicted in (2) is to be used to analyze compliance cost, special care must be exercised in the construction of the process alternatives. Specifically, we are concerned with mass balance and to a lesser degree energy balance. Since the environmental regulation of an industry is generally concerned with the emission of industrial byproducts, or pollutants (henceforth termed residual outputs), all such products must be accounted for in the process model at each stage of production. Simply stated, everything which enters the model as an input must be traced through its physical transformations to a final output. The maintenance of materials balance in the process model permits the influence of a regulation pertaining to one or more residuals to be traced through the entire sequence of production.

The completed process model will be employed to mimic a firm or industry's response to a given Federal regulation. Naturally what we are concerned with is the marginal impact (incremental cost) of the regulation; thus, if an industry is already treating its waste water streams to recover valuable byproducts, for example, we will want to be sure that our process model incorporates that fact in the preregulation base case. Therefore, in addition to having the important properties of process consistency and materials balance, the process modeler will also strive to construct a model which depicts actual production practices, especially in the area of pollutant generation, abatement, and treatment.

Before proceeding further into the discussion of the process model approach, a few characteristics of the process model methodology need to be highlighted.

- First and foremost, the process model is frictionless, that is, it does not permit less than instantaneous adjustment to relative factor price changes and environmental regulation.

- Second, the model is purely static and does not permit technological change or the impact of new technology diffusion.

- Third, the optimization rule provides the mechanism for choosing process alternatives; it is not intended as an explanation of process choices actually made by firms. Moreover, the model always chooses the ideal configuration or processes in a world of perfect certainty; therefore, it does not allow for the adoption of suboptimal process alternatives as a special case.

- Fourth, the distinction between ex ante and ex post analysis of a proposed regulation versus an existing regulation is not meaningful in the process model context since the model has no time dimension. All compliance cost estimation is essentially ex ante.

4.2.2 Process Models and Specific Classes of Environmental Regulations

We shall not attempt in this section to discuss the analysis of specific environmental regulations using a process model; but rather, we will examine the broad range of generic regulations amenable to analysis and depict how the process model would be configured for each class of regulations. Five classes of environmental regulations are given below; each class is characterized by the variables of the process model which are impacted.

- Regulations which alter relative input prices
- Regulations which limit input quantities
- Regulations which restrict residual emissions
- Regulations which tax residual emissions
- Regulations which restrict process choice

The first class of regulations we shall discuss are those which affect the relative prices of factor inputs. Such regulations could take the form of subsidies with respect to the purchase of treatment equipment or taxes placed upon the use of particular inputs such as fresh water. Regulations which affect input prices are the simplest to model in a process framework and merely involve the substitution of the old input price vector with the new vector incorporating the affected prices. The optimization problem (3) depicts how the stylized process model of (2) is redesignated to analyze this first class of regulations.

$$\begin{aligned} &\text{Minimize:} && \bar{p}'x && (3)\\ &\text{S.T.} && y \geq y^0 \\ & && (x,y) \in T(x,y) \\ & && \bar{p} \geq 0 \end{aligned}$$

where: $\bar{p}$ = the vector of input prices which now reflect the presence of an environmental regulation

For the purpose of analysis the model (3) is solved once using the vector p prices (preregulation input prices) and once using the vector $\bar{p}$ prices (post regulation prices). Given the two solutions, several aspects of the regulation's effect can be ascertained. First, the difference in the value of the objective function provides an insight to the regulation's impact on the private cost of production to the firm or industry. We use the term private cost since the regulation has distorted the market for inputs and thus the firm's cost of production will not necessarily bear directly on social cost. Second, we can examine the optimal demands for factors of production in the preregulation and postregulation states of the world. This is clearly an important aspect of the analysis since an environmental policy may affect a factor of production which is the target of an unrelated but important Government policy. Certainly we would want to determine the impact of the regulation on the demands for labor and energy.

In addition to the simple cost and factor demand analyses suggested above, the process model allows one to view the intricacies of the engineering adjustments made in response to a regulation. Given the base case solution of the model at p prices, we are able to determine the specific set of processes adopted and the scale at which each process is operated. When the model is run at $\bar{p}$ prices the model adjusts its optimal configuration of processes and their scales. While not relevant to the present class of regulation (those which affect input prices), some types of regulations can alter the overall engineering efficiency of the production activity. This engineering efficiency, which we shall term technical efficiency, will often be disguised in the objective function due to simultaneous changes in process alternatives, but may be perceived from a direct examination of the optimal processes chosen.[17]

Finally, the process analysis model permits the investigation of residual switching in response to a specific regulation. Residual switching would occur if regulations on waterborne residual discharges were in place while airborne discharge regulation was absent. In the case of iron and steel production, waterborne residuals generated in the finishing section would be piped back to quench coke and thus the residuals would be discharged through evaporation into the air mantle. Since all residuals are tracked through the production activity, residual switching can be directly perceived.

Summarizing briefly, we have identified four ex ante analyses of compliance cost which can be conducted with the use of process models. The first, termed private cost analysis, focuses on the incremental private compliance cost associated with a particular regulation. Such analysis, based on the change in per unit production cost, captures both direct and indirect effects and is properly defined as incremental if the base case analysis (model (2)) is constructed according to our guidelines.[18] The second, factor demand analysis, concerns the potential for altered factor intensities and thus individual factor rewards and productivities. The third, efficiency analysis, deals with overall productivity of the production activity, and the fourth, residual analysis, concerns the effect of a regulation designed to alter the emission of one residual on the emission of all residuals.

The second class of regulations has the effect of limiting the inputs of certain factors of production. Again one could imagine limitations on the quantities of fresh water consumed or regulation banning the burning of high sulfur coal. In all cases this class of regulations merely imposes an additional set of constraints on the model. If x_c is a subset of the impact vector x and x_c are those inputs constrained by regulation, the process model appears as (4).

$$\begin{aligned} &\underset{x}{\text{Minimize:}} && p'x && (4)\\ &\text{S.T.} && y \geq y^0 \\ &&& (x,y) \in T(x,y) \\ &&& p \geq 0 \\ &&& x_c \leq x_c^0 \end{aligned}$$

where: x_c^0 = vector of constraining input levels.

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The same types of impact analyses discussed with regard to (3) can be performed on (4). Those analyses are: 1) private cost analysis, 2) factor demand analysis, 3) efficiency analysis, and 4) residuals analysis.

The third class of regulations are those which directly restrict the discharge of residuals. This is clearly the most popular form of environmental regulation and one which is readily handled within the process model framework. Partition the output set y into two subsets, y_q which are the desired market oriented outputs and y_r which are the residual outputs. Bear in mind that this partitioning is a function of market prices and particular outputs can move between two subsets as these market prices change. Consider regulations on the residual subset which place upper limits on their disposal. The process model incorporating this class of regulations is given in (5).

$$\begin{aligned} \underset{x}{\text{Minimize:}} \quad & p'x && (5) \\ \text{S.T.} \quad & y_q \geq y_q^0 \\ & (x,y) \,\varepsilon\, T(x,y) \\ & y = \begin{pmatrix} y_q \\ y_r \end{pmatrix} \\ & p \geq 0 \\ & y_r \leq y_r^0 \end{aligned}$$

where: y_q^0 = specified level of market outputs

y_r^0 = maximum level of residual discharges

Comparing the optimal value of the objective function from (5) with the value generated by the unconstrained technology (2) provides an estimate of the full private cost of the regulation $y_r \leq y_r^0$. The cost differential resulting from the regulation is a composite of direct and indirect impacts on the production activity in question. The direct impacts are those closely associated with the reduction of discharges; for example, the cost of treatment and abatement capital, and the labor, energy and materials necessary for its operation. The indirect impacts are less easy to identify since they emanate from efficiency gains or losses that have resulted from the reorganization of the process activities in an attempt to reduce discharges. While these indirect impacts may be hard to identify individually (such identifications require the type of efficiency analysis discussed above), they are accurately accounted for, along with the direct impacts, in the value of the objective function.

The fourth class of regulations we shall consider are those which act as a tax or fee on the discharge of residual outputs. Let the vector t represent the schedule of per unit taxes or fees applied to the discharage of residual outputs y_r. In the absence of other environmental regulations the discharge-tax model appears as (6).

$$
\begin{aligned}
&\underset{(x,y_r)}{\text{Minimize:}} \quad p'x + t'y_r && (6)\\
&\text{S.T.} \quad y_q \geq y_q^0 \\
&(x,y) \,\varepsilon\, T(x,y) \\
&y = \begin{pmatrix} y_q \\ y_r \end{pmatrix} \\
&p \geq 0 \\
&t \gtrless 0
\end{aligned}
$$

where: t = a vector of taxes on y_r if $t > 0$ or subsidies if $t \leq 0$.

Analysis of the above regulation is quite straightforward. Following the analysis methodology discussed previously, one would examine: private cost (objective function), factor demands, process efficiencies, and residuals discharges.[19]

A modification to (6), which would reduce the private compliance cost of discharge-tax regulation and bring the model closer to reality, would be to permit the sale of usable byproducts captured by the residual discharge treatment equipment. An example is the spent sulfuric acid used in the finishing sections of steel plants. Taxing the discharge of the spent acid induces the firm to treat the finishing section waste streams and capture the acid. The recovered acid is then sold in the market at a positive p[illegible], thus offsetting the cost of recovery.[20] To incorporate the effects of byproduct recovery induced by regulation, one can modify the objective function of (6) or (5) by subtracting the byproduct sale revenue. The modified objective function is given in (7).

$$\underset{(x,y_r,y_{qr})}{\text{Minimize:}} \quad p'x + (t'y_r - p_r'y_{qr}) \tag{7}$$

where: p_r = a vector of market prices for recovered byproducts

y_{qr} = a vector of marketable recovered byproducts

The term $t'y_r - p_r'y_{qr}$ represents the net direct private cost of discharge-tax regulation. Evaluating the objective function (7) relative to a base case of no regulation such as (2) provides an estimate of the direct and indirect private cost of regulation.

The last class of regulations we will discuss are those which require the adoption of particular processes, such as scrubbers. This type of regulation normally augments the technology set T by including processes which are tangential to the production activity. Let us denote this augmented technology by $\hat{T}$. We further define individual process within the set $\hat{T}$ by (x,y). With this added notation in hand we may proceed to the process model and define the appropriate constraints.

$$\underset{x}{\text{Minimize:}} \quad p'x \tag{8}$$

$$\text{S.T.} \quad y \geq y^0$$

$$(x,y) \in \hat{T}(x,y)$$

$$(\bar{x},\bar{y}) \in (x,y)$$

$$p \geq 0$$

where: $(\bar{x},\bar{y})$ is the process which must be adopted and the subscripts on y have been dropped since we are no longer directly concerned with residuals.

The first constraint, $y \geq y^0$ is the usual output requirement; the second, $(x,y) \in \hat{T}(x,y)$ merely requires that the chosen set of process alternatives be elements of the augmented technology $\hat{T}$; the third constraint requires that a particular process, such as scrubbers, be an element of the set of optimal process alternatives, (x,y), and the fourth merely requires that input prices be nonnegative. The analysis of this class of regulations proceeds through the steps as those outlined earlier, namely, cost analysis, factor demand analysis, efficiency analysis, and residuals analysis.

The six models discussed above, (2)-(7), have all assumed that the firm or industry facing a particular environmental regulation will continue to produce a given vector of marketable outputs. In the case of iron and steel, used in the illustrations above, this required level of output would include a menu of steel ingots, semifinished shapes, plate, strip, and wire products.

In reality, environmental regulations affect the output decisions we have arbitrarily held constant. To capture the impact of regulation on these output decisions, we cast the process model in a profit maximizing mode. In such a mode the model chooses simultaneously both the levels of output and factor demands. In the absence of regulation the model would appear as (9).[21]

$$\begin{aligned} &\underset{(x,y)}{\text{Maximize:}}\quad p_q'y - p'x \\ &\text{S.T.}\quad (x,y)\ \varepsilon\ T(x,y) \\ &\qquad p_q, p \geq 0 \end{aligned} \tag{9}$$

where: p_q = a vector of prices for the market ouputs

$p_q'y$ = total revenue from the sale of y

$p'x$ = total factor cost

The model depicted by the optimization problem (9) makes a stronger assumption about the production activity it seeks to represent than does the earlier model (2). In (2) cost minimization was chosen as the optimizing rule which served to select from the technology set those process alternatives which were least cost. Presumably (2) mimics the selection of process alternatives actually made by firms and industries. In (9) the optimizing rule is profit maximization; and the model determines not only the least cost process alternatives but also the mix and quantities of outputs to produce. To link the results of (9) to actual firm or industry decisions we must assume that the firm seeks to maximize profit.

Given we are content with the profit maximizing assumption, (9) provides the basis for the same regulatory analysis as the preceding cost minimization models. In addition, (9) permits us to examine the impact of regulation on the firm's output decisions and provides us with some insight as to the regulatory effect on profitability. The model given in (9) is thus richer in its analytic power than the previous cost minimization models.

4.3 Neoclassical-Econometric Models of Production Activity

4.3.1 Overview of the Model

The contemporary econometric model of production is similar to the process model in several respects, but is fundamentally different in its methodology. The econometric model is constructed as a tool of explanation, designed to explain the behavior of economic agents controlling production activities. Unlike the process model, the econometric model can not be used as an aid to production management, nor can it supply information concerning the optimal process configurations. The reason behind these inabilities lies in the structure of the model, which infers characteristics of the underlying technology from observable economic phenomena (factor prices and demands) emanating from the decisions of economic agents. In contrast, the process model infers the decisions of the economic agents (process choices and factor demands) from the characteristics of the technology.

Underlying the econometric model of production is the neoclassical theory of the firm. The firm is composed of a set of economic agents (decisionmakers) who purchase factors of production and organize those factors to produce a set of intended marketable outputs. The firm is a dynamic enterprise, which exists through time and is assumed to optimize some intertemporal objective function, such as profit, sales, revenue, or growth. Optimization of the objective function subject to the constraints imposed by the technology determines the optimal demands for factors of production and the optimal mix and scale of outputs to produce. The actual process alternatives adopted to produce the intended outputs are observable in the neoclassical-econometric model.

Let us consider a version of the econometric model which might be compared to the process model depicted by the optimization problem (2). We shall assume that the firm, whose production activity we are investigating, is minimizing total cost subject to an output constraint. Employing the notation of the previous section we would model the firm's decisionmaking problem as the simple optimization problem displayed below.

$$\begin{aligned} &\underset{x}{\text{Minimize:}} \quad p'x \\ &\text{S.T.} \quad y \geq y^0 \\ &\qquad (x,y) \in T(x,y) \\ &\qquad p \geq 0 \end{aligned} \tag{10}$$

Given some minimal regularity conditions on the set T, the necessary conditions for a cost minimum are also sufficient.[22] Solving the necessary conditions in terms of the input vector x gives rise to a system of optimal factor demand functions of the form (11).

$$x^* = h(p,y) \tag{11}$$

These demand functions express the optimal quantities of factors to be employed by the firm as a function of factor prices and the level of output.

At this stage of development the neoclassical-econometric model appears quite similar to the engineering process model. We have identified the optimal rule (cost minimization)--a procedure quite analogous to the process model. However, if we reverse the problem and use knowledge of x* we can indirectly determine the properties of T(x,y).

To infer the technology from the factor demands we introduce the notion of the cost function. At a cost minimum, total cost is given by (12).

$$c = p'x^* \qquad (12)$$

If we substitute the factor demand equations (11) into (12) we obtain an expression for minimum total cost as a function of input prices and output. The resulting minimum cost function is given in (13).

$$c = c(p,y) \qquad (13)$$

A signficant property of cost functions was discovered by Ronald Shephard and published in 1953.[23] The result followed from Shephard's investigation of duality properties inherent in economic optimization problems and has since been termed Shephard's lemma. We merely provide Shephard's result without derivation.[24] Shephard's lemma states, given certain regularity conditions on T, the first derivatives of the cost function with respect to input prices generate the optimal factor demands as described by (14).

$$\frac{\partial c(p,y)}{\partial p} = x^* = h(p,y) \qquad (14)$$

Thus, we can derive an expression for optimal factor demands by differentiating the cost function rather than deriving and solving the first order conditions of (10). Since we no longer need to deal directly with (10) we do not require explicit information concerning T(x,y); indeed, characteristics of T(x,y) can be approximated from c(p,y).

We have undertaken this rather formal presentation of the cost function since it is the standard analytical tool in the contemporary neoclassical-econometric model of production. It is hoped that our presentation has also highlighted the fundamental difference between the engineering process model and the econometric model; namely, the process model requires explicit knowledge of the engineering character of production to assemble the technology set T(x,y), whereas the econometric model only requires information on the observable economic variables x^*, p, and y.

So far, our discussion of the neoclassical-econometric model has made no reference to the purely econometric issues associated with the model, and we intend no detailed discussion of these issues since such a discussion would take us beyond the scope of this paper. However, we do need to highlight some characteristics of the model which are derived from its econometric nature. First, the model is only as good as the data (observations on x^*, p, and y) used to estimate it. Second, ex ante analyses which push the model beyond its range of experience are less reliable than those analyses performed within the range of experience. The range of experience is defined by the observed variation in x^*, p, and y which was used to estimate the model originally. If a particular environmental regulation forces firms to use new and untried technologies, ex ante econometric analyses of the regulation will push beyond the model's range of experience and will force the model to extrapolate its results to these unexperienced regions. Finally, if we intend to draw from the model analyses of regulations which involve the interactions of factor demands x^*, intended outputs y_o, and discharged residuals y_r, the data used to estimate the model must contain sufficient orthogonal variation in these variables. That is, we must be able to observe variation in discharges which are moderately uncorrelated with variations in intended output and factor demand.

These caveats expressed with regard to econometric models are not unique to these models but hold with equal force with respect to engineering process models. Clearly, the process model is only as good as the engineering data used to construct it. Moreover, the process model has a fixed range of experience given by its set of process alternatives and the model is incapable of extrapolating beyond its range of experience.

4.3.2 Econometric Models and the Analysis of Environmental Regulations

During our discussion of process models we examined five broad classes of environmental regulations and showed how the process model could be employed to analyze the impact of these regulations on firms or industries. We begin our examination of the econometric model by reconsidering four of these five classes of regulations. Specifically we will consider:

- Regulations which alter relative input prices
- Regulations which limit input quantities
- Regulations which restrict residual emissions
- Regulations which tax residential emissions

For each class of regulation we will illustrate how an ex ante analysis of the regulatory impact would be conducted.[25]

We assume as given, the existence of a neoclassical-econometric model of the production activity in question. The model we will be working with has the following form:

Cost function: $c = c(p,y)$ (15)

Input demand functions: $x^* = h(p,y)$ (16)

where: c = total minimum cost of production

p = a vector of factor prices

y = a vector of outputs

x^* = a vector of optimal factor demands

In addition, we assume analytical forms have been assigned to the functions $c(p,y)$ and $h(p,y)$, and the parameters of these forms have been previously estimated.

An examination of the first class of regulations, those which affect the price of one or more inputs, is easily carried out within the context of the econometric model. Assume the regulations have altered the preregulation price vector p and denote the new postregulation price vector $\bar{p}$. The preregulation econometric model is represented by equations (15) and (16). When the preregulation prices are inserted into the model we are able to calculate the total cost and factor demands in the preregulation environment. We use these calculations as the base case in our ex ante analysis of the regulations. Inserting $\bar{p}$ into (15) and (16) provides estimates of the postregulation total cost $\bar{c}$ and factor demands $\bar{x}^*$. The post regulation equations are given below.

$$\bar{c} = c(\bar{p},y) \qquad (17)$$

$$\bar{x} = h(\bar{p},y) \qquad (18)$$

The total direct and indirect impacts of the regulation are found through a comparison of c and $\bar{c}$, while a comparison of x^* and $\bar{x}^*$ provides a measure of the factor demand effect. Since this form of regulation has only an effect on relative input prices, one would again not expect a loss in technical efficiency to occur. Finally, we are unable to analyze the pattern of residual discharges in this regulatory environment since there are no economic or institutional (regulatory) forces acting on the firm to control its discharges.[26]

The ex ante analysis of regulations which in some sense limit input quantities is more interesting than those regulations which affect input prices, since limitations on factor inputs force the firm to be allocatively inefficient.[27] Allocative inefficiency occurs when the first order conditions for a cost minimum are violated. For the sake of illustration let us assume that the production technology we are concerned with employs only two inputs x_1 and x_2 and provides a single intended output y. In the preregulation environment the econometric cost function and factor demand functions appear as follows:

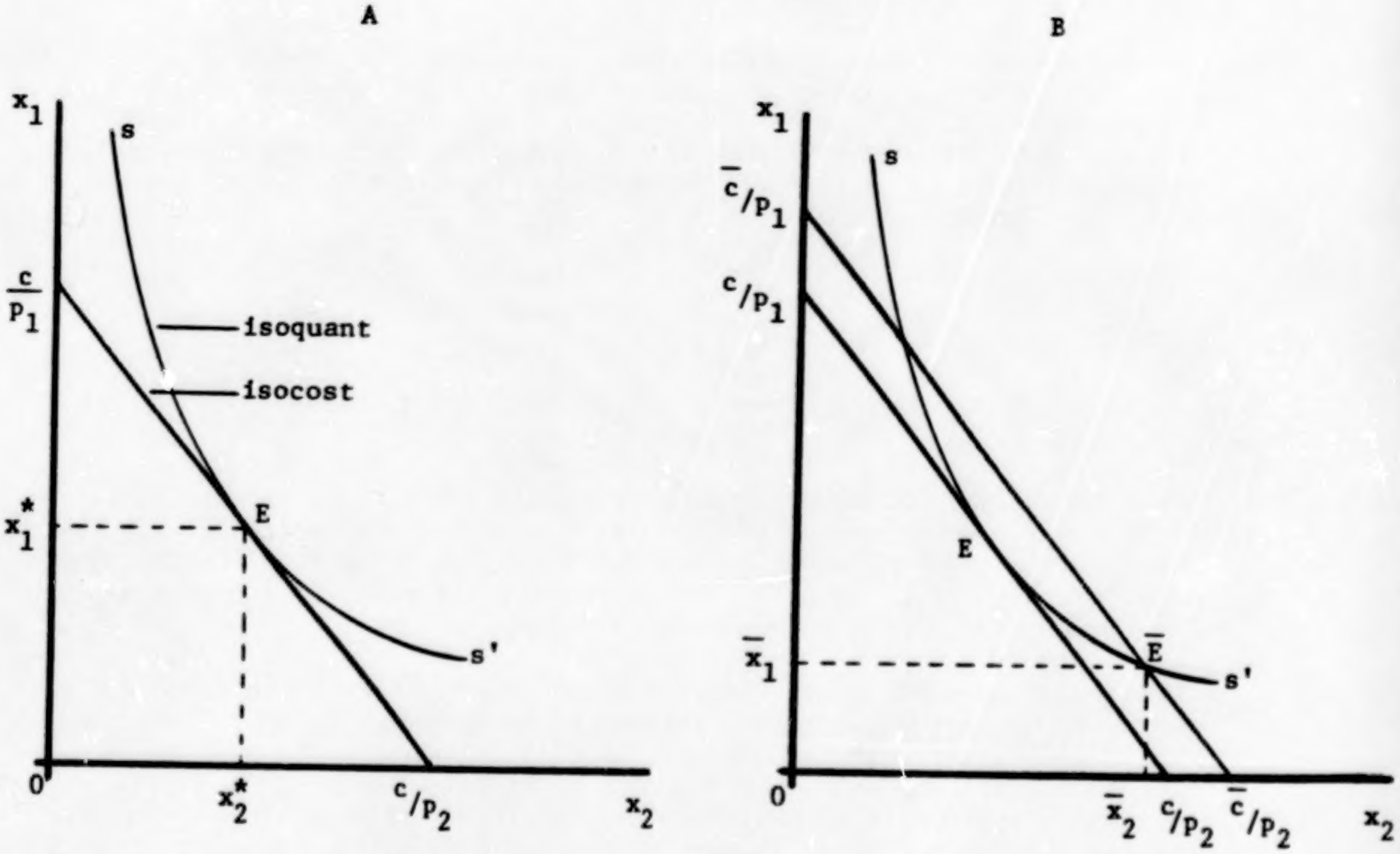
$$c = c(p_1,p_2,y) \qquad (19)$$

$$x_1^* = h_1(p_1,p_2,y) \qquad (20)$$

$$x_2^* = h_2(p_1,p_2,y) \qquad (21)$$

The cost-minimizing equilibrium of the firm characterized by equations (19) - (21) is depicted graphically in panel A of figure 1. The curve ss'

Figure 1



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is the isoquant corresponding to output level y for this production activity and the isocost line corresponds to a total cost of c. The tangency between the isoquant and the isocost at point E determines the cost minimum and the optimal factor demands x_1^* and x_2^*. Now consider a proposed regulation which limits the quantity of input x_1 to a maximum of $\bar{x}_1$. Given this regulation the firm is forced to move from point E to point $\bar{E}$ (panel B) on the isoquant. The new total cost at $\bar{E}$ is $\bar{c}$ and the difference between c and $\bar{c}$ is the cost of allocative inefficiency brought about by the regulation.

The determination of c, x_1, and x_2 from the econometric model (19) - (21) is not as straightforwarad as it appears from the diagram and involves the simultaneous solution of equations (19) - (21). Briefly sketching the solution, we fix x_1 at its constraint level $\bar{x}_1$ in equation (20) but allow its price p_1 to vary. We then solve for the new $\bar{p}_1$ and using $\bar{p}_1$, p_2, and $\bar{x}$, we solve for x_2. The new higher total cost $\bar{c}$[28] is found by summing the expenditures on x_1 and x_2, that is, $p_1x_1 = p_2x_2$.

The third class of regulations are those which limit the discharge of residuals. To perform an ex ante review of this type of regulation we utilize the output vector partition in y_q (intended outputs) and y_r (residual discharges). An econometric model of the form (15), (16) incorporating the output partition (y_q, y_r) is estimated, and the general form of the model is given in (22) and (23) below.

$$c = c(p, y_q, y_r) \qquad (22)$$

$$x^* = h(p, y_q, y_r) \qquad (23)$$

After the parameters of the model have been estimated, the regulated level of residual discharges $\bar{y}_r$ is substituted in (22) and (23) along with the specified level of intended outputs and the price vector of inputs. The model is then simulated to predict postregulation $\bar{c}$ and factor demands $\bar{x}^*$. The remainder of the ex ante analysis proceeds as usual.

The ex ante analysis of regulations which impose a tax on the discharge of residuals must employ indirect econometric techniques. These indirect methods are employed since the ex ante, preregulation environment provides no economic or institutional forces which would motivate the firm to control residual discharges. Without such forces an economic model seeking to explain the pattern of discharges cannot be constructed. In such a world the best we can do is explain cost and factor demand from a model like (22), (23) which is conditioned upon a given level of residuals discharge and intended output production.

In order to measure the ex ante impact of a residuals discharge tax on a firm's production activity we analyze the shadow cost to the firm of a reduction in its discharges. Since, in the preregulation world, the price of discharges to the firm is zero, one would expect the cost minimizing firm to discharge residuals up to the point where the discharges no longer had a beneficial impact (positive marginal product) on the production of intended outputs. If the firm is forced to discharge less than this optimal amount, the cost of producing the same level of intended output will be higher in the presence of discharge constraints. This additional cost can be termed the shadow cost of the discharge constraint. If a tax on discharges was levied equal to the shadow cost mentioned above, the firm would voluntarily limit its discharges to the point coincident with the aforementioned discharge constraint.

Implementing this indirect econometric approach, using the previously discussed model (22), (23), merely requires differentiating the cost function (22) with respect to the levels of discharge y_r. The resulting functions state how the cost of producing a given level of intended output changes as discharges change. One might expect these functions to be U-shaped, as displayed in figure 2. The unconstrained, untaxed firm would fix its discharges optimally at $y_r{}^*$. If we now institute a tax of t on per unit discharges, the firm will reduce its discharges to y_r. To actually compute y_r from (22) we differentiate (22) with respect to y_r and set this derivative equal to t as given by (24) below.

$$t = \partial c(p, y_q, y_r)/\partial y_r \qquad (24)$$

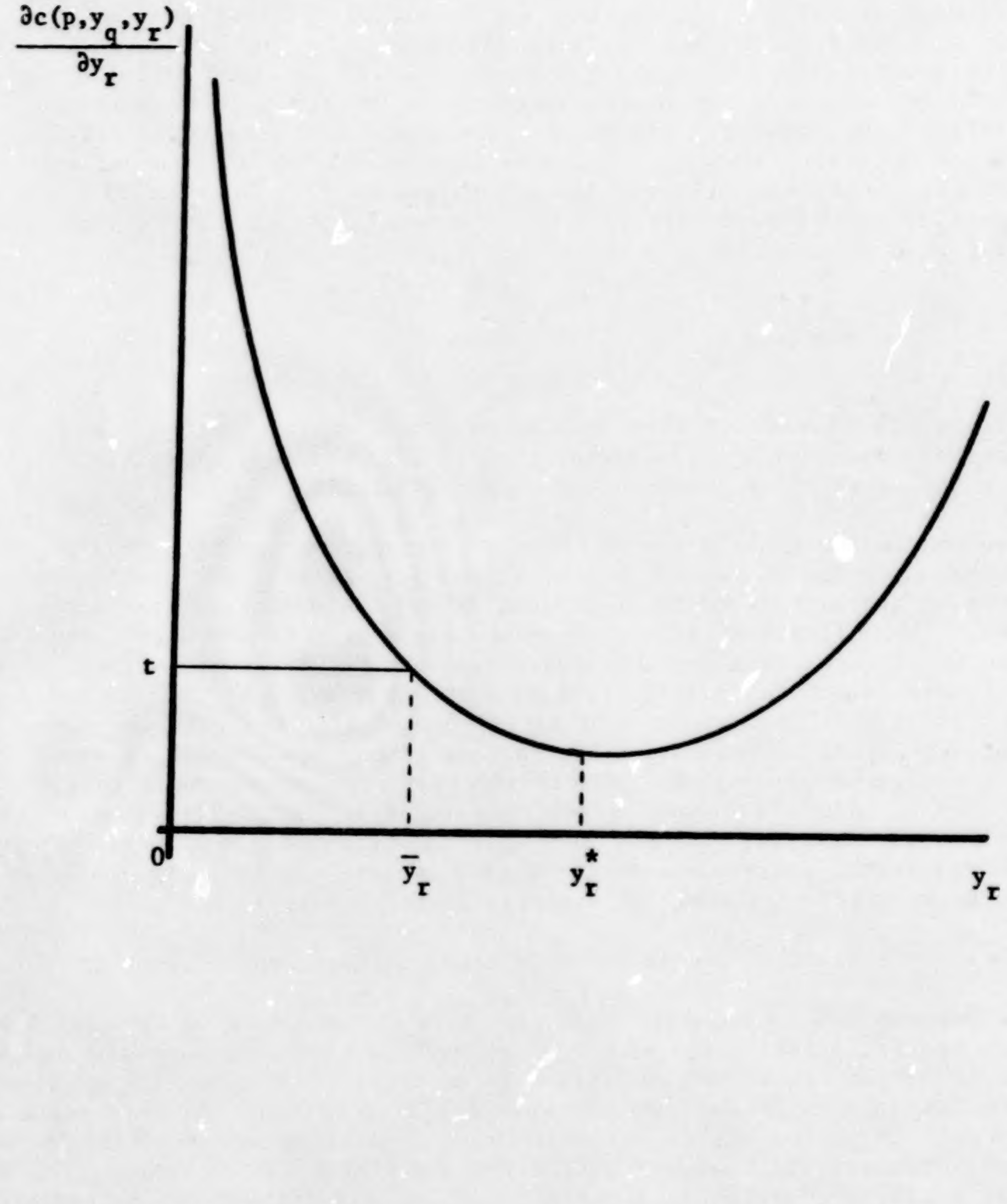
Solving (24) for y_r in terms of the exogenous variables p, y_q, and t provides estimates of $\bar{y}_r$. Inserting $\bar{y}_r$ into (22) and (23) generates estimates of $\bar{c}$ and $\bar{x}^*$ which are used in the ex ante analysis.

Some concluding remarks are in order with respect to ex ante regulatory evaluation using the framework of the econometric model. First, the analyses focus on the private costs of production and the demand for productive factors. The analysis of production costs captures both the direct and indirect impacts of regulation and thus considers both technical and allocative inefficiencies which may spread throughout the production process as the result of regulation. The analysis of factor demand also reflects the direct and indirect impact of regulation but in this case the impact is realized through altered factor proportions. Since the post regulation proportions may run counter to other Governmental policies (such as energy conservation), may inhibit productivity, or may lead to redistributions of income through altered factor shares, the factor demand impacts can be quite important and not fully realized through an analysis of total cost alone.

4.3.3 Some Often Overlooked Regulatory Costs: Dynamic Impacts

The process and econometric models we have discussed up to this point have been static, frictionless models which have no time dimension and instantaneously adjust from one equilibrium to another, in response to an exogenous stimulus in the form of an environmental regulation. In this static, smoothly adjusting world, the impacts of regulation are realized through the static private costs of production and static factor demands. In the real world, production is a dynamic affair, and factors are not adjusted costlessly and instantaneously but adjust with a lag and at a positive cost.

Figure 2



Moreover, firms are intertemporal and must make decisions today which will affect their operation in subsequent years. Examples of such decisions include research and development projects, and optimal capital maintenance and scrappage schedules.[29] Given that firms and their production activities are dynamic, some thought must be given to the dynamic impact of regulation.

Let us first consider the short-run versus the long-run regulatory impact. We define the short run as a time dimension in which a subset of factor inputs are variable and the remaining inputs are quasi-fixed (that is, not variable in the short run); in the long run all factors are variable. Quasi-fixed variables are usually composed of capital stocks but may also include such things as fixed labor contracts. Since some variables are incapable of adjustment in the short run, the firm is not able to move directly to a least-cost equilibrium in response to an imposed regulation. This limited adjustment ability will lead to a greater short-run regulatory impact on total cost than on long-run costs. Consequently, static process and econometric models will tend to underestimate the short-run impacts since they are essentially long-run models.[30]

Fortunately, short-run and long-run econometric models do exist and can be easily adapted to the problem of regulation analysis; unfortunately no such process models exist. A simple but powerful dynamic econometric model is the _partial static equilibrium_ model.[31] The model permits a subset of the factor inputs to costlessly adjust to an equilibrium conditioned on a set of quasi-fixed inputs which do not adjust. In this context the firm's cost minimization leads to a _restricted cost_ function of the following form.

$$c = c(p_v, y, \hat{x}) \qquad (25)$$

where: c = minimum variable cost

p_v = a vector of variable factor prices

y = a vector of outputs

$\hat{x}$ = a vector of quasi-fixed factors

In essence (25) is a short-run cost function associated with a set of short-run variable factor demand functions given in (26).

$$x_v^* = h(p_v, y, \hat{x}) \qquad (26)$$

where: x_v^* = a vector of optimal variable factor demands

The short-run model represented by equations (25) and (26) can be used to examine the short-run impacts of all four classes of regulation discussed in the previous section.

To find the long-run cost function corresponding to (25) we make use of the envelope theorem in economic theory. For any given level of output and variable input prices there is a unique level of x that will minimize all costs. If x is set at this equilibrium level, denoted x*, then the firm is in full long-run equilibrium with respect to all factors of production and the corresponding long-run cost function is given by (27).

$$c^* = c(p_v, y, \hat{x}) + p_{\hat{x}}\hat{x}^* \qquad (27)$$

where: c = minimum total cost

$p_{\hat{x}}$ = a price vector for the quasi-fixed inputs

If we allow all input prices (both variable and quasi-fixed) and output to vary we can generate a set of short-run cost functions. The envelope of all these short-run functions, which traces the locus of minimum long-run total cost, is the long-run cost function depicted by equation (27). The long-run cost function (27) is associated with a set of long-run factor demand functions for both variable and quasi-fixed inputs, enabling a companion long-run examination of regulatory impacts.

In the partial static equilibrium model the short-run and long-run equilibriums are two distinct states of the dynamic production activity; and the transition between these two states is neither explained nor observed. There exists a second class of dynamic models which explicitly consider the adjustment from a short-run partial equilibrium to a long-run full equilibrium. This model explains the process of adjustment on the basis of internal adjustment costs.[32] Paralleling the partial static equilibrium model, the internal cost of adjustment model also dichotomizes inputs into variable and quasi-fixed categories. The variable factors can be adjusted at zero cost to the firm, while the quasi-fixed factors can only be adjusted at positive cost. The faster the rate of adjustment, the greater the cost.

The internal cost of adjustment model depicts not only short-run and long-run equilibriums but also the dynamic path of quasi-fixed factor adjustment and an expression for the adjustment costs themselves. In general, adjustment costs are found to be a function of the changes in quasi-fixed factor stocks, the levels of output, the level of quasi-fixed factor stocks, and the prices of variable inputs as depicted by equation (29).

$$\tilde{c} = \tilde{c}(\hat{x}, \Delta\hat{x}, y, p_v) \qquad (29)$$

where: $\tilde{c}$ = the cost of a given change in the levels of quasi-fixed factors per unit of time.

$\Delta\hat{x}$ = the change in quasi-fixed factor stocks per unit of time

$\hat{x}, y, p_v$: as previously defined

If a dynamic internal cost of adjustment industry model was estimated, impacts on adjustment costs of regulations which affect levels of quasi-fixed stocks could be determined. It is important to point out that these adjustment costs are incurred in addition to the static direct and indirect costs discussed previously. The lower the speed of optimal quasi-fixed stock adjustment, the greater will be the internal adjustment cost of a change in quasi-fixed stocks mandated by regulation. Industries with typically low speeds of adjustment include: textile mill products; lumber products; stone, clay, and glass products; electrical machinery; non-electrical machinery; petroleum refining; and primary metals.

Probably the most important dynamic impact a regulation can have would be to affect technological advance and innovation diffusion. Since firms must make research and development decisions in a world of imperfect foresight and uncertainty, it is not clear whether such an impact would result in a private (or social) loss or gain. It is quite conceivable that a particular regulation could serve to speed up the adoption of a highly efficient innovation or could just as conceivably forestall such adoptions. Unfortunately, the neoclassical-econometric model can provide little useful information in this regard since it does not presently incorporate a well-developed theory of technological advance or innovation diffusion.

5.0 Practical Problems with Ex Ante Compliance Cost Estimation

In the preceding sections we have discussed three approaches to the problem of ex ante compliance cost estimation; these are 1) the input cost accounting approach, 2) the engineering process model, and 3) the neoclassical econometric model. The practical problems associated with the input cost accounting approach have already been discussed in some detail and we shall not elaborate further on them. Our intention in this section is to examine the problems associated with the process and econometric model approaches to compliance cost and to suggest some avenues of future research.

5.1 Problems Associated with Process and Econometric Models

There can be no doubt that the engineering process model is an extremely useful tool for the ex ante analysis of environmental regulation. The model's ability to identify and accurately account for indirect costs and the phenomena of residual switching serve to distinguish it from the more crude input cost accounting methods. However, the model does have some inherent weakenesses and problems of implementation.

The major weakness of the process model is its lack of a time dimension. This timeless character of the model implies that all production activities occur instantaneously and that alterations in these activities (for example, process changes resulting from regulation) also occur immediately and costlessly. Moreover, the model is poorly equipped to deal with technological change and the diffusion of innovation; thus, it is largely unsuitable for analyses of regulatory impacts on the process of innovation.

The major implementation problem associated with the process model is cost. At the present time only a handful of process models exist which are capable of undertaking the types of compliance cost estimation suggested in section IV. The small number of such models is a direct result of the enormous effort which must be undertaken to construct a credible model. Upon completion of the model there still exists the cost associated with model maintenance which would include periodic updates of the technology matrix to incorporate new processes and changes in the structure of the industry the model is designed to depict. Finally, the high degree of specificity in a credible model implies that the model construction, maintenance, and results are not easily generalizable to other production activities; and thus, numerous self-contained models must be constructed to encompass the industrial sector of a modern economy.

The practical problems of process models are faily well understood since we have experience (albeit, minimal experience) in the construction and use of such models for the analysis of environmental regulation. On the other hand, the neoclassical econometric approach to compliance cost estimation is still in its formative stages, and thus we have little practical experience with the methodology. Two studies do exist which employ the formal neoclassical model in the analysis of environmental regulation. The first, Kopp [1980], studied the relationship between levels of residuals discharges and measures of technical efficiency in the U.S. electric power industry; the second, Pittman [1981], examined the impact of environmental regulation on the cost structure of paper mills. Unfortunately, the limited nature of these studies provides only a partial understanding of the problems to be faced if the econometric model approach is to be employed on a large scale to estimate ex ante compliance cost.

One practical limitation of the econometric modeling approach is clear--it is data-intensive. The quantity of data required will depend upon the level of technological disaggregation (i.e., 4, 3, or 2-digit Standard Industrial Code designations and plant, firm, or industry organization) dictated by the analysis. But regardless of the aggregation, the model will require the prices and quantities of all inputs consumed and marketable outputs produced plus estimates of residual discharges. Collecting the input and output data will be a costly task in itself; however such data do exist and have been routinely collected and used by econometricians to study production activities for some time. The task of collecting the residual discharge estimates poses a more uncertain cost. For some sectors of the economy the task will be quite straightforward since residual discharge estimates are readily available; the obvious example is U.S. steam electric generation, where residual discharge estimates have been collected for several years. For other industrial sectors EPA estimates may have to be employed.

The potential advantages of the econometric approach make it a reasonable alternative to the process model for ex ante compliance cost estimation. Aside from the initial data collection effort, the cost of econometric model construction, estimation, and maintenance is miniscule when compared to that of the process model. Moreover, the econometric model can be given a time dimension permitting one to examine the adjustment cost associated with a regulation in a dynamic setting. Finally, properly designed econometric models of industrial activity mesh well with other economic models used for policy analysis, such as large scale macroeconometric models.

The major practical problem associated with the econometric approach is its reliability. Past experience with process models has shown that they provide reasonably good approximations to actual engineering activities and can be expected to perform adequately in the complex analysis of compliance cost. Econometric models, on the other hand, do rather well in depicting factor demand, but can they reliably forecast compliance cost? The results of econometric models are sensitive to technological and input aggregation and to model misspecification, but even under ideal aggregation conditions and proper specification it is unclear whether the complexity of firms' adjustments to regulation can be adequately captured and predicted by a model which is intended only as a summary of major causal forces. Unfortunately, we have little practical experience with econometric models incorporationg discharge data upon which to base a judgment concerning the usefulness of the underlying econometric methodology.

5.2 Some Topics for Research

In the body of this paper we have asserted that the ex ante analysis of compliance cost can be improved if process models and/or econometric models are used instead of, or in conjunction with, the input cost accounting approach. Given our claim, a logical research strategy would be to establish an empirical test of the assertion. Such a test would simultaneously provide insight regarding the credibility of our proposals and would also generate experience in using process and econometric models which may uncover previously unknown practical problems or advantages.

Considering first the process model approach, it seems reasonable to circumvent the construction stage and use one of the currently available off-the-shelf models as a guinea pig. The research plan would involve choosing a particular regulation or a set of regulations to be analyzed. The process model would then be configured in a preregulation base case environment and solved. Next the model would be reconfigured in the postregulation environment and resolved. The types of compliance cost analyses discussed in section IV would then be executed. As a test of the model's validity one could choose a regulation already in place where the ex post cost data on hand are assumed to be of high quality. Using the process model we would then perform an ex ante analysis and determine how well the ex ante estimates compared to the actual ex post cost.

A test of the econometric approach is considerably more complicated than the process model. Since high quality econometric models of the kind required for ex ante estimation do not currently exist, a test methodology similar to the process model would first require the construction of a suitable econometric model. The cost of this initial construction, including data collection, can be expected to be quite high. Moreover, even if such a model were constructed and tested, we would not be able to determine the differential impact on the quality of the results emanating from poor model construction or from an underlying inadequate methodology. As we stated above, it is the econometric methodology which is really at issue and which we seek to test, not a specific model. Thus before any wholesale testing of econometric models begins, a plan to evaluate the econometric methodology must first be devised.

FOOTNOTES

1. For a review and discussion of the macroeconomic effects of environmental regulation, see Peskin, Portney, and Kneese [1981].

2. See DeMuth [1980] for the most comprehensive discussion of the pros and cons of the regulatory budget.

3. For a fuller discussion of these issues see Peskin, Portney, and Kneese [1981].

4. See Portney [1981].

5. *Ibid*.

6. This section draws largely on material presented in Portney [1981].

7. See Andersen [1979].

8. *Ibid*., p. 26.

9. For a discussion of the allocative inefficiencies that result from tax-exempt financing of pollution control, see Peterson and Galper [1975].

10. For an analysis of such mechanisms, see Sonstelie [1981].

11. For instance, see Securities and Exchange Commission Administrative Proceeding File No. 3-5936. See also Salpukas [1979].

12. See Sonstelie [1981].

13. For a discussion of other possible uses of these kinds of approaches, see Vaughan [1978].

14. See Portney [1981].

15. An excellent description of the process model approach and its applicability to environmental regulation can be found in Russell and Vaughan [1976].

16. We have taken some liberty with the notation used to describe the process model in order to utilize one set of notation consistently throughout the paper.

17. Technical efficiency is a concept attributed to Farrell [1957]. Its only known application to the case of environmental regulation is found in Kopp [1980]. A full description of Farrell's early contribution and several generalizations to it are found in Kopp [1981].

18. A methodology for analyzing both direct and indirect impacts of environmental regulation using an econometric model is found in Kopp and Smith [1981].

19. In this case we would subtract from the value of the model (6) objective function the value of the tax $t'y_r$, in order to perceive how the actual costs of production net of the tax were altered by the imposition of the tax. Naturally, if we were concerned with total private compliance cost including the tax, $t'y_r$ would remain in the calculated value of the objective function.

20. If in the preregulation environment it was profitable to recover marketable byproducts we would want to make sure that the base case objective function of model (2) included $p_r y_{qr}$.

21. We should point out that if the process model is characterized by constant returns to scale and further that it can utilize any quantity of inputs at a fixed price without limit, it will tend to expand production infinitely. In actual applications one would normally restrict the quantity of capital the model can employ.

22. These conditions are found in Diewert [1974].

23. See Shephard [1953].

24. A formal and most useful proof is contained in Diewert [1974].

25. Unfortunately, the econometric model is incapable of examining the regulatory impact of a required process adoption, since it does not identify the individual processes.

26. Since in both the preregulation and postregulation environments there are no costs to a firm for its pollution, the firm faces no constraints on its polluting behavior. Without such constraints the economic model of production is incapable of determining how the residual discharges will change with a given change in the price of factor inputs.

27. Discussions of allocative efficiency can be found in Farrell [1957] and Kopp [1981].

28. A full solution to this problem can be found in Kopp and Diewert [1981].

29. See Kopp and Smith [1980] for a theoretical discussion of these issues.

30. Of course, if the econometric model is estimated with short-run data then it will tend to overestimate the long-run effects.

31. The model is fully described in Brown and Christensen [1981].

32. See Berndt, Fuss, and Waverman [1977] for a more detailed discussion.

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REGULATORY COSTS AND TECHNOLOGICAL INNOVATION
THE FEDERAL EXPERIENCE WITH THE AUTOMOBILE INDUSTRY

by

Joseph A. Vasquez, Jr.
ICF, Inc.

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PART I: OVERVIEW

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1.0 Introduction

The automobile is the centerpiece of the U.S. passenger transportation system. According to a recent Department of Transportation (DOT) report on the U.S. Automobile Industry,[1] auto travel accounts for approximately 83 percent of all intercity passenger miles and approximately 96 percent of all travel within cities. Automobile and truck production represents a significant component of our economy, accounting for about 8 percent of our Gross National Product (GNP) and 25 percent of U.S. retail sales.

Because of the automobile's pervasive role in our economy and personal lives, the automobile and the automobile industry[2] have become the subject of a wide variety of Federal regulations that impose direct and indirect costs and benefits on both the manufactuers and consumers of automobiles. The Environmental Protection Agency (EPA) regulates the levels of hydrocarbons, carbon monoxide, nitrous oxides, sulfur oxides, and lead emissions from automobiles. EPA also regulates the emissions of harmful substances (volatile organic compounds) during the automobile manufacturing process. The Department of Transportation promulgates safety standards and fuel economy requirements for automobiles. The Department of Energy (DOE) promulgates regulations that are designed to influence the price of automobile fuels, and to promote research and development of highway vehicles and systems. In January of 1981, there were 71 recent and pending Federal regulatory activities that were promulgated to regulate the sale or operation of motor vehicles (cars and trucks).[3] These recent and pending regulatory activities did not include the substantial body of existing regulations promulgated and implemented prior to January of 1981.

The domestic automobile industry is experiencing depressed sales, record losses, and severe unemployment. This has prompted various Federal officials to consider policy alternatives including "regulatory relief" to help strengthen the auto industry.[4] Although the Federal Government has a large and diverse collection of data concerning the costs and effects that automobile regulations have on the automobile industry, consumers, and the economy, the data are often not adequate to support the decisionmaking process. Significant pieces of data are missing. Frequently, the data that are available are based on inconsistent or contradictory assumptions. These deficiencies prevent the development of aggregate impact estimates or comparison of costs and benefits among the regulations.

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[1] The U.S. Automobile Industry, 1980, Report to the President from the Secretary of Transporation, U.S. Department of Transportation, January 1981.

[2] For the purposes of this paper, General Motors Corporation, Ford Motor Company, Chrysler Corporation, and American Motors Corporation.

[3] Source: The Automobile Calendar: Recent and Pending Activities Affecting Motor Vehicles, prepared by ICF Incorporated for the U.S. Regulatory Council, January 1981.

[4] See: Actions To Help the U.S. Auto Industry, The White House, April 6, 1981.

This paper presents the results of cost estimates of Federal automobile emissions control regulations promulgated by EPA (and the Department of Health, Education, and Welfare) since 1966 and all EPA and DOT regulations affecting the production and sale of motor vehicles pending as of January 1, 1981. The presentation is divided into two parts. The first part examines (1) estimates of the costs associated with Federal automobile emissions control regulations and promulgated since 1966 and (2) cost estimates prepared for all DOT and EPA regulations affecting the automobile industry pending as of January 1981. The second part examines the impact of emissions control regulations on research and development (R&D) investments made by domestic automobile manufacturers.

It is our desire to help policy officials better understand the regulatory process by addressing two fundamental sets of questions.

First, are adequate cost estimates of Federal regulations affecting the manufacture and sale of automobiles available and what are the problems associated with existing estimates? Is it possible to prepare estimates of the aggregate cost of Federal regulation of the automobile? Are cost estimates of Federal regulations comparable? Should guidelines be developed to ensure that useful cost estimates are prepared for all Federal regulations?

We are interested in the comparability of cost estimates in addition to the adequacy of individual estimates designed to meet the unique requirements of a particular decisionmaking process. Executive branch policy officials must regularly make tradeoffs among regulatory proposals. They must assess the ability of the economy or a single industry to bear the regulatory costs and burdens necessary to achieve regulatory objectives. The Secretary of Transportation for example must determine how much the automobile industry can bear to achieve fuel economy objectives while also meeting vehicle safety standards. The Secretary must make tradeoffs between the cost, or cost-effectiveness, of safety and fuel economy regulations. The President must consider tradeoffs between an even broader array of regulatory programs. In the case of the automobile industry, the President must consider not only DOT fuel economy and safety regulations, but also EPA emissions control regulations. Therefore, while regulatory impact analyses might require supplemental information to meet the unique requirements of their particular decisionmaking process, it is essential that all regulatory impact analyses contain comparable estimates of critical cost components to enable executive branch officials to make enlightened policy decisions when they must choose among various regulatory proposals. Part II, therefore, attempts to determine whether regulatory cost estimates are comparable or whether they provide the basis for developing aggregate cost estimates.

The second set of questions we address considers the effect of Federal automobile emissions control regulations on innovation in the automobile industry. That is, have Federal mobile source emissions control regulations induced automobile manufacturers to undertake additional investments in emissions control technology R&D?

This paper examines industrial investment in R&D rather than "innovation" as it is traditionally defined in a scientific or engineering context. We recognize that there may be problems associated with using R&D expenditures as a proxy for innovation.[5] However, there is little information available concerning the relationship between technological innovation in the automobile industry and emissions control regulations. This paper represents an initial attempt at examining this relationship based on the limited available data base.

This paper is divided into the following major sections:

PART I: OVERVIEW

Section 1.0 Introduction

Section 2.0 Executive Summary

PART II: REGULATORY COSTS

Section 3.0 Costs of EPA Automobile Emissions Control Regulations.

Section 4.0 Costs of EPA and DOT Motor Vehicle Regulations.

PART III: TECHNOLOGICAL INNOVATION

Section 5.0 Emissions Control R&D and Federal Regulations.

2.0 Executive Summary

The Executive Summary is divided into two sections corresponding to the major parts of this paper--Part II: Regulatory Costs and Part III: Technological Innovation.

2.1 PART II: REGULATORY COSTS

2.1.1 Overview

In Part II, we examine estimates of the costs of 50 Federal motor vehicle EPA emissions control and DOT fuel economy and safety regulations. These regulations are listed in Appendix D. We also examine nine separate cost estimates prepared since 1969 for EPA automobile emissions control regulations. These nine studies are listed in Exhibit 3.2. By examining cost estimates for various motor vehicle regulations we hoped to answer the following questions.

---

[5] For a discussion of the problems associated with developing a linkage between regulations and R&D expenditures see The Impact on Industrial Innovation of Environment, Health, and Safety (EHS) Regulations, Morrison, R.E., National Science Foundation, March 1979.

- Are cost estimates available?
- Are available cost estimates complete? That is, do they provide estimates of all significant cost components?
- Are available cost estimates comparable? That is, are the assumptions and methods used to prepare cost estimates consistent?
- Can an aggregate estimate of the cost of Federal motor vehicle regulations be prepared using the available cost estimates?

In the Costs of Federal EPA Automobile Emissions Control Regulations section, Section 3.0, we reviewed a series of cost analyses prepared over the last decade for one type of Federal regulation--EPA automobile emissions control regulations. We found that the studies examined did not consistently provide estimates for the same cost components or employ consistent methods for estimating costs. Therefore, it is difficult to compare cost estimates provided by the different studies. We did not observe any significant trends in the development of regulatory cost estimating techniques over time.

In the Costs of EPA and DOT Motor Vehicle Regulations Section, Section 4.0, we reviewed 50 cost analyses recently prepared for a variety of Federal regulations--EPA motor vehicle emissions control regulations and DOT fuel economy and safety regulations. As in Section 3.0, we found that the cost analyses examined did not consistently provide estimates for the same components of costs or employ consistent methods for estimating costs. Therefore it is difficult to compare cost estimates for different regulations and it is not possible to prepare an aggregate estimate of the combined costs of Federal automobile regulations from these estimates.

2.1.2 Availability and Status of Cost Estimates

We have examined the availability and status of cost estimates for 50 regulatory proposals pending as of January of 1981. That is, these proposals had either not been promulgated as final rules, or they had been promulgated as final rules but had an effective date after January 1981. Of the 50 proposals we examined, 28 were promulgated as notices of proposed rulemaking (NPRM) and 22 were at the pre-NPRM stage. Proposals at the pre-NPRM stage usually represent preliminary proposals designed to elicit comments and alternative proposals and are frequently revised or abandoned. Rigorous estimates of the costs and benefits of pre-NPRM proposals are not usually developed.

Exhibit 2.1 presents our findings of the availability and status of cost estimates for the 50 proposals we examined. The first two columns present our findings for all 50 regulations. The second two columns present our findings for the subset of the 50 regulations that had reached the NPRM stage.

As illustrated in Exhibit 2.1, fairly complete cost information is available for 17, or 34 percent, of the cost estimates for the 50 regulatory proposals examined in Section 4.0. Of the 28 of the 50 proposals that had reached the NPRM stage, fairly complete information was available for 50 percent, or 14, of the proposals. No cost information was available for 42 percent, or 21, of the 50 proposals. If only proposals at the NPRM stage are considered, cost estimates were not available for 14 percent, or 4, of these 28 regulations.

EXHIBIT 2.1

AVAILABILITY OF COST INFORMATION FOR EPA AND DOT REGULATORY PROPOSALS AS OF JANUARY 1981

	Pre-NPRM and NPRM Stage		NPRM Stage	
	No.	%	No.	%
Fairly Complete	17	34	14	50
Limited	12	24	10	36
None	21	42	4	14
Total	50	100	28	100

2.1.3 Comparability and Status of Cost Estimates

The cost estimates we examined for various regulations that were available, are not directly comparable. This is because they either omit significant cost components, they use different input assumptions and estimating methods, or they do not provide adequate documentation. In sections 3.0 and 4.0, we find that it is difficult, if not impossible, to compare estimates prepared for automobile emissions control, safety, and fuel economy regulations. In Section 3.0, we examined nine estimates prepared since 1969 for emissions control regulations. In Section 4.0, we examined current estimates prepared by EPA and DOT for 50 different pending regulations.

The significant problems identified in Sections 3.0 and 4.0 of this paper are summarized in Exhibit 2.2. We have identified three types of problems: (1) omissions of cost components, (2) inadequate documentation, and (3) methodological differences. Recommendations designed to address these problems are also presented in this exhibit. The following methodological problems were identified.

- o Sales Projections. Different sales projections and sales projection techniques are used to estimate costs. Not all projections provide for consumer responses to price changes, and those that do use different price response assumptions (price elasticities).

- Consumers' Costs. Estimates of consumers' operation and maintenance costs are significantly different in three ways. First, they use different methods for estimating changes in fuel economy (vehicle weight trend adjustment methods). Second, they use different fuel price assumption and price calculation methods (retail price vs. production costs for unleaded fuel). Third, they use different methods for estimating maintenance costs attributable to regulations (total vs. incremental requirements).

- Manufacturers' Costs. None of the studies examined adjusts for costs attributable to more than one regulation. Industry homogeneity is usually assumed and learning curve effects are not considered.

- Hardware Costs. Studies use different baseline hardware configurations. Retail prices are estimated using different methods (actual vs. retail price equivalent), and retail price equivalent estimates use different markup factors.

- Price Level Index. Studies frequently do not indicate price level index or do not properly adjust prices taken from previous studies.

- Gasoline Price and Grade. Studies use different gasoline price assumptions, or do not indicate price or gasoline grade assumptions.

- Discount Factor. Studies do not specify discount factors used and appear to use different discount factors.

- Consumer Demand. Studies do not attribute any costs of product modification to consumer demand or changes in consumer preferences.

2.1.4 Conclusions

Our findings suggest that DOT and EPA should follow standard regulatory cost analysis guidelines to ensure the preparation of both complete and comparable estimates of the costs associated with Federal motor vehicle regulations. We have not been able to identify substantive arguments supporting the use of different methods for the regulations and regulatory cost estimates reviewed in this paper and summarized in Exhibit 2.2. Furthermore, we have not identified methodological differences where improvements or developments in recent years justify the use of different methods in the preparation of regulatory cost estimates. Where there may be substantive reasons for applying different methods, we would not suggest sacrificing accuracy for consistency.

EXHIBIT 2.2

SUMMARY OF FINDINGS
SECTIONS 3.0 AND 4.0 COST ESTIMATES OF FEDERAL AUTOMOBILE REGULATIONS

Item	Problems	Recommendation
Sales Projections	Inadequate Documentation. Few studies examined indicate vehicle sales levels or sales base used to amortize fixed costs (Sec. 3.4.2.2. and Sec. 4.3.3.1). Methodological Problems. Sales projection are not consistent (Sec. 4.3.3.1). Treatment of consumer responses to prices is not consistent (Sec. 4.3.3.2).	Sales projections should be adjusted to reflect consumer responses to price changes. An agency (EPA, DOT, or OMB) should be designated to coordinate or specify sales projections assumptions and consumer price elasticities.
Consumers' Costs - Fuel Consumption Penalty/ Savings	Inadequate Documentation. Six of the nine studies examined do not adequately describe the fuel consumption of baseline vehicles, methods of measuring fuel Consumption, and fleet consumption assumptions. (Sec. 3.4.2.4)	Miles per gallon of baseline fleet and and current fleet should be provided.
Consumers' Costs - Maintenance Costs	Inadequate Documentation. Only two studies adequately itemize maintenance costs of each hardware component. (Sec. 3.4.2.3). Two studies omit documentation of scheduled maintenance routines. (Sec. 3.4.2.3) Methodological Problems. Four different methods for vehicle weight trend adjustments are used by nine applicable studies. (Sec. 3.4.3.3)	Consumer maintenance costs attributed to a regulation should only include incremental costs. The maintenance schedules, and the costs associated with each item on the maintenance schedule should be specified. The EPA should develop a method of vehicle weight trend adjustments.
Consumers' Costs - Unleaded Price Penalty	Omission of Cost Component. Three of six applicable studies do not estimate unleaded price penalties. Inadequate Documentation. Two of the three studies that provide estimates describe the components of the unleaded price penalty costs. (Sec. 3.4.2.5) Methodological Problems. Two methods are used to determine unleaded gas prices (actual retail price vs. production and distribution cost methods). (Sec. 3.4.3.4)	Methods used to determine the unleaded price penalties, or the consumer cost estimates based on the price of unleaded gasoline, should be specified.

EXHIBIT 2.2 (continued)

Item	Methodological Problems	Recommendation
Manufacturers' Costs	Omission of Cost Component. Aggregate and unit cost estimates are not provided. (Sec. 4.3.1.1) Inadequate Documentation. Components (such as R&D, capital) are not specified. (Sec. 4.3.1.1) Methodological Problems. No studies appear to adjust for costs attributable to more than one regulation. (Sec. 3.4.3.6, and Sec. 4.3.1.2). Industry homogeneity and learning curve assumptions are not addressed. (Sec. 4.3.1.4)	Specify both unit and aggregate cost estimates. Learning curve effects should be addressed and where possible problems arising from industry homogeneity assumptions should be addressed.
Hardware Costs	Inadequate Documentation. Four out of nine studies specify hardware components costs. (Sec. 3.4.2.2) Analyses of 9 of 50 proposals describe assumptions for retail markup factors. (Sec. 4.3.2.1) Methodological Problems. Different baselines are used for various estimates. Two cost methods are used--Actual and Retail Price Equivalent methods. (Sec. 3.4.3.1) Inconsistent Retail Price Equivalent markup factors are used. (Sec. 4.3.2.1)	Specify all emissions control systems components. Specify if Retail Price Equivalent or Actual Price Method is used. In either case, the source of cost estimates should be identified.
Price Level Index	Inadequate Documentation. Four of nine studies do not describe price index. (Sec. 3.4.2.1) Methodological Problems. Two studies use costs from previous studies without properly adjusting price indices. (Sec. 3.4.2.1)	Convert all cost estimates to current real dollars. One agency (OMB, Treasury) should be designated to conduct or define price level index assumptions.
Gasoline Price and Grade	Inadequate Documentation. Price and grade of gasoline not provided. (Sec. 3.4.2.1) Methodological Problems. Different prices are used by different studies. (Sec. 3.4.2.1 and Sec. 4.2.2.2)	A single agency (DOE or OMB) should be designated to coordinate or specify all price assumptions.
Discount Factor	Inadequate Documentation. No indication of discount factors used. (Sec. 3.4.2.1)	A single agency (EPA, DOT, or OMB) should be designated to coordinate or specify all discount factor assumptions.

Vehicle Lifetime Mileage	Inadequate Documentation. Five of nine studies do not indicate vehicle lifetime mileage. (Sec. 3.4.2.1)	A single agency (EPA, ODT, or OMB) should be designated to coordinate or specify all vehicle lifetime mileage assumptions (100,000 for automobile).
Consumer Demand	Methodological Problems. No studies attribute any component of product changes to consumer demand or preferences; all costs are attributed to Federal regulations. (Sec. 4.3.1.3)	Agencies should attempt to estimate the impact of changes in consumer preferences and in manufacturers' product plans. Only the cost of product modifications not resulting from changes in consumer preferences should be attributed to Federal regulations.

The provision of estimates for all components of costs and the provision of adequate documentation of cost estimates is, of course, our first and foremost recommendation. This is an essential first step to enable policymakers to compare the costs of regulations and to assess the aggregate costs of Federal motor vehicle regulations. Once EPA and DOT are able to provide complete and well-documented cost estimates, care should be taken to ensure that the assumptions and methods used to develop these estimates are comparable and that aggregate estimates of the total costs of Federal regulations can be developed.

We note that our review of regulatory cost estimates for automobile emissions control, safety, and fuel economy regulations does not address estimates prepared by automobile manufacturers or automobile parts manufacturers and suppliers. There is considerable variation among estimates prepared by Federal agencies and the various companies that either manufacture automobiles or provide parts or supplies to automobile manufacturers. Disagreements over cost estimates are usually one of the most critical aspects of debates over regulatory proposals.

Our cursory review of several industry cost estimates suggests that industry and Federal agency cost estimates are not always comparable. These estimates are frequently prepared using apparently different assumptions and methods. This tends to obscure the debate over the substantive merits of regulatory proposals.

To promote the objective debate of the substantive merits of regulatory proposals, the concerned Federal agencies should work with industry representatives to identify the assumptions and methods used to prepare cost estimates. Differences should be identified, and where possible comparable methods and assumptions should be established. If disagreements concerning assumptions and methods cannot be resolved, each party might consider developing estimates of cost components based on each set of assumptions to facilitate a comparison of industry and Federal estimates. We recognize that there may be many differences among various participants in the regulatory process and that our proposal is preliminary and requires further consideration and critical analyses. We only suggest here that this issue requires further consideration to promote the objective evaluation of regulatory programs by policy officials.

2.2 PART III: TECHNOLOGICAL INNOVATION

2.2.1 Overview

In Part III of this paper, we examine the effects of Federal automobile emissions controls regulations on emissions controls R&D expenditures by automobile manufacturers (GM, Ford, Chrysler, and AMC). R&D expenditures are considered here as a proxy for innovation.

In Section 4.1 we hypothesize that if we identify periods when the automobile industry did not anticipate the promulgation of Federal emissions control regulations, expenditures for emission controls R&D should be low. Similarly, if we identify periods when the automobile industry did anticipate the promulgation of Federal emission control regulations, expenditures for emission controls R&D should be high.

We identified two periods since 1967 when the automobile industry anticipated that Federal eimssions standards would not be promulgated (1967-70 and 1975-77) and two periods when the automobile industry anticipated that standards would be promulgated (1971-74 and 1978-80).

We developed estimates of annual automobile industry R&D expenditures for emissions controls since 1967 to test our hypothesis. These estimates were based on industry reports.

2.2.2 Findings

The emissions controls R&D expenditures estimates developed and presented in Part III of this paper are summarized in Exhibit 2.3 (same as Exhibit 5.2). These data tend to support our hypothesis. Emissions controls R&D expenditures declined in Period I (1967-70) and Period III (1975-77). Emissions controls R&D expenditures increased in Period II (1971-74) and Period IV (1978-80).

EXHIBIT 2.3
(same as EXHIBIT 5.2)

SUMMARY OF R&D EXPENDITURES FOR EMISSIONS CONTROLS
BY DOMESTIC AUTOMOBILE MANUFACTURERS* FROM 1967 TO 1980

Period		Expected Level of Investment in Emissions Control R&D	Actual Annual Average Expenditures for Emissions Control R&D (millions of 1980$)	Expenditures for Emissions Controls R&D as a Percentage of Sales
Period I	1967-70**	low	$186	0.2
Period II	1971-73	high	$571	0.5
Period III	1974-77	low	$559	0.4
Period IV	1978-80	high	$672	0.5

*General Motors Corporation, Ford Motor Company, Chrysler Corporation, American Motors Corporation.

**We were not able to prepare estimates for 1964 through 1966.

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Furthermore, Congress adopted a strong "technology forcing" policy with the 1970 Amendments to the Clean Air Act. We, therefore, expected to see more substantial R&D expenditures after the promulgation of regulations implementing the 1970 Amendments (Periods II, III, and IV) than before the amendments (Period I). As Exhibit 2.3 demonstrates, this hypothesis is also supported by the data. The annual average emissions controls R&D expenditures in Periods II, III, and IV were $586 million. Prior to the 1970 Clean Air Act Amendments (Period I), annual average expenditures were $186 million or about one-third the annual average after the amendments.

2.2.3 Conclusions

The annual patterns of our estimates of industry expenditures for emission controls R&D since 1967 tend to support the notion that these expenditures were in part the result of strict Federal emissions control regulations. If R&D expenditures represent a proxy for technological innovation, then one might argue that Federal regulations induced innovation in the technological development of emissions control systems.

This does not imply that these Federal regulations did not also impose costs associated with diverting scarce R&D resources away from other efforts.

There are several qualifications that should be noted concerning estimates of emissions controls R&D expenditures presented in Section 4.0. These emission controls R&D expenditures estimates:

- do not include R&D expenditures by automobile parts manufacturers and suppliers.
- do not include expenditures by automobile manufacturers on R&D contracts with other organizations.
- were based on data provided by the manufacturers. We have not confirmed the manufacturers' estimates based on an independent review.

PART II: REGULATORY COSTS

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3.0 Costs of Federal EPA Automobile Emissions Control Regulations

3.1 Overview

This section examines estimates of the costs of Federal automobile emissions control regulations. The Federal automobile emissions control regulations we examine in this section have been promulgated over a 16 year period, as a series of progressively more stringent limitations on the amounts of three pollutants--hydrocarbons (HC), carbon monoxide (CO), and nitrous oxides (NOx)--allowed to be emitted from automobiles. We will not consider here Federal regulation of sulfur oxides and lead. The series of standards we consider here is summarized in Exhibit 3.1.

EXHIBIT 3.1

FEDERAL AUTOMOBILE EMISSIONS CONTROL STANDARDS FOR MODEL YEARS 1970 TO 1981

Standard (HC/CO/NOx in grams per mile)	Model Year
3.9/33.3/ -	1970, 1971
3.4/39/-	1972
3.4/39/3.0	1973, 1974
1.5/15/3.1	1975, 1976
1.5/15/2.0	1977, 1978, 1979
.41/7.0/2.0	1980
.41/3.4/1.0	1981

Note: Standards are based on the CVS-CH test procedure (cold volume sampling, cold and hot start) or the CVS-CH equivalent of the standard promulgated based on the CVS-C test procedure.

The costs of controlling automobile emissions are a matter of great concern to policymakers, the automobile industry, and the consumers who eventually must bear much of the burden of these costs. The cost of meeting the strict standards originally set by Congress and EPA has proven to be an instrumental factor in the long history of delays and suspensions of the standards. The automobile industry was either unable or unwilling to produce cars that could meet the original strict schedule of standards at a reasonable price or with reasonable performance and fuel consumption. Even now, when most automobile producers are making cars that meet standards very close to the original standards set by Congress in 1970, the manufacturers still maintain that the costs associated with this level of control are excessive relative to the benefits provided.

Congress, in the Clean Air Act Amendments of 1970, required EPA to set standards that would reflect the legislated emissions reductions, but granted the agency no authority to consider costs when setting the standards. However, in the 1970 Amendments, EPA was instructed to submit to Congress annual reports of the estimated costs of compliance with the standards. Cost estimates have also been developed by other government agencies and ad-hoc groups, by bodies such as the NAS, and by automobile manufacturers. Substantial differences in the costs estimated by different groups at different times can be observed.

Indeed, the costs and benefits of exhaust emissions control are now a matter of intense debate during the current congressional hearings concerning the reauthorization of the Clean Air Act. The cost-effectiveness or cost/benefit ratio of mobile source emission regulations will be a critical factor in Congress' determination of the severity of the emissions standards they establish for the next decade.

However, a cost/benefit or cost-effectiveness analysis is only as good as its inputs. This section offers a critical analysis of past cost estimates of automobile emissions control regulations, the key inputs to a cost/benefit or cost-effectiveness study. It is our intention to identify methodological problems of cost estimates prepared for automobile emissions control regulation over the last decade, and to suggest ways that future analyses address these problems. We hope to offer legislators, Government officials, industry groups, and concerned citizens an understanding of the assumptions and methods behind the numbers. In the next section, we will examine EPA regulations as well as DOT regulations to determine if the problems identified in this section exist for a broader array of Federal regulations.

This section of our study is divided into three parts. First, four components of the overall cost of emissions regulations are identified and defined. Second, a summary of the standardized results[6] of nine major studies of cost estimates prepared over the last 13 years for the costs of automobile emissions control regulations is presented. Third, the inconsistencies among the studies and the inadequacies of the regulatory cost accounting techniques employed over this 16-year period are identified.

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[6] To facilitate comparison of estimates of costs among the nine studies we standardized the cost estimates by recalculating cost estimates for each study using the study's original methodology but substituting consistent input assumptions (such as price of gas, technology baseline, discount rates). A complete description of the procedures we used to standardize cost estimates is provided in Appendix A.

3.2 Costs Addressed in This Study

This section is based on a retrospective cost analysis of automobile emissions control standards performed for the Intergovernmental Regulatory Liaison Group.[7] The retrospective cost analysis addressed nine studies of the costs of automobile emissions standards, prepared either by EPA (with the cooperation of other Federal agencies) or the National Academy of Sciences (NAS). The studies are listed in Exhibit 3.2. Other Government agencies, including the Council of Environmental Quality, the Cost of Living Council, and the Office of Science and Technology Policy, and the automobile industry itself, have also developed cost estimates. However, the examination of cost estimates developed outside of EPA and NAS was beyond the scope of the retrospective cost analysis and hence not addressed here.

The unit costs of purchasing and operating a car are addressed in this paper. The aggregate costs to the Nation are not considered, even though these costs are estimated in some form or another by most of the studies that were examined. This is not meant to imply that costs to the Nation are not as important as unit costs. They are excluded because few of the studies address costs to the Nation in a clear and unambiguous manner. Only the costs of purchasing and operating Otto cycle gasoline powered automobiles are examined. Light duty diesel or rotary engine automobiles are not examined due to lack of sufficient historical data.

This paper focuses on the increased overall cost to the consumer of purchasing and operating an automobile due to modifications made to comply with automobile emission standards. The overall cost can be broken down into four basic components: hardware costs, maintenance costs, fuel consumption penalty costs, and unleaded price penalty costs. The following dicussion defines these four costs.

Hardware Costs: The cost of modifications or additions to the car body or engine attributable to meeting the pollution control standard for a given model year is considered to be the hardware cost of that model year. This is often referred to as the "first cost," because it reflects what the consumer pays when the automobile is first purchased, as opposed to expenses incurred later during operation of the vehicle.

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[7] Retrospective Analysis of Cost Estimates for EPA Automobile Emission Control Regulations: 1970-1981 (Final Draft), prepared by ICF Incorporated for the U.S. Environmental Protection Agency, May 1981.

EXHIBIT 3.2

MAJOR STUDIES OF THE COST OF AUTOMOBILE EMISSIONS CONTROL REGULATIONS 1969 TO 1979

Study	Abbreviation
The Cost of Clean Air 1969, U.S. Environmental Protection Agency, June, 1969.	CC69
The Economics of Clean Air 1971, U.S. Environmental Protection Agency, March 1971.	EC71
The Economics of Clean Air 1972, U.S. Environmental Protection Agency, February 1972.	EC72
The Cost of Clean Air 1974, U.S. Environmental Protection Agency, July 1974.	CC74
Analysis of Some Effects of Several Specified Alternative Automobile Emission Control Schedules (Dingell Report), Economic Policy Board, April 8, 1976.	DR76
Analysis of Effects of Several Specified Alternative Automobile Emission Control Schedules Upon Fuel Economy and Costs (Five Agency Study): U.S. Department of Commerce, U.S. Department of Transportation, U.S. Energy Research and Development Administration, U.S. Environmental Protection Agency, and U.S. Federal Energy Administration, February 1977.	5A77
An Analysis of Alternative Motor Vehicle Emission Standards (Three Agency Study): U.S. Department of Transportation, U.S. Environmental Protection Agency, U.S. Federal Energy Administration, May 19, 1977.	3A77
The Cost of Clean Air and Water 1979, U.S Environmental Protection Agency, August 1979.	CC79
Report of the Committee on Motor Vehicle Emissions 1974, National Academy of Sciences, September 1974.	NAS74

Maintenance Costs: The nonfuel costs to the consumer of operating and maintaining a car over its useful lifetime attributable to meeting the emission control standards are maintenance costs. Usually, only the costs of scheduled maintenance procedures (as opposed to unanticipated repairs) are included. The costs of Inspection/Maintenance Programs are not included. According to some of the nine studies, certain of the changes made to the cars actually decrease the frequency of maintenance routines. Therefore, there can be savings in maintenance costs due to pollution control systems. The maintenance costs (or benefits) reported in this study are the net costs (or benefits) due to pollution control regulations.

Fuel Consumption Penalty Costs: Fuel consumption penalty costs[8] are defined as the cost of the additional fuel consumed by a car over its useful lifetime attributable to the changes made to the car to comply with emissions control standards. Emissions control measures that have a significant impact on fuel economy are summarized in Exhibit 3.3.

Unleaded Price Penalty Costs: The catalytic converter has been an integral part of pollution control systems for most cars since model year 1975. The catalytic converter can function properly only if unleaded gasoline is used by the motorist. The use of leaded gasoline will in a short time deactivate the catalyst, rendering it unable to control exhaust emissions. The introduction of unleaded fuel to the marketplace in the mid-1970s was done solely to protect the catalytic converter from deactivation. Therefore, the extra costs to the consumer of unleaded gasoline are fully attributable to automobile pollution control standards. The unleaded price penalty costs, then, are the costs to the motorist of paying a higher price for unleaded fuel over the lifetime of the vehicle. The unleaded price penalty costs are calculated based on the unleaded differential which is defined as the difference in cost per gallon between regular and unleaded gasoline.[9]

A clear distinction should be made between the fuel consumption penalty and the unleaded price penalty. The fuel consumption penalty costs, as defined in this study, reflect the effects of increased consumption of gasoline.

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[8] The dollar value of the fuel consumption penalty is calculated as follows using a standard price of fuel of 50¢ per gallon (this is the current price of fuel in 1967 dollars):

$$\begin{array}{l}\text{Dollar Value}\\ \quad\text{of}\\ \text{Fuel Penalty}\end{array} = \frac{\left[\begin{array}{c}\text{Fuel Penalty/Benefit}\\ \text{expressed as a per-}\\ \text{centage gain/loss}\end{array}\right]\left[\begin{array}{c}\text{100,000 miles}\\ \text{lifetime mileage}\end{array}\right]\left[\begin{array}{c}\text{Price of}\\ \text{fuel:}\\ \text{50¢/gal}\end{array}\right]}{[\text{MPG of model year under consideration}]}$$

[9] The dollar value of the unleaded price penalty is calculated as follows:

$$\begin{array}{l}\text{Unleaded}\\ \text{Price}\\ \text{Penalty}\end{array} = \frac{\left[\begin{array}{c}\text{100,000 miles}\\ \text{lifetime}\\ \text{mileage}\end{array}\right]\left[\begin{array}{c}\text{Unleaded Differ-}\\ \text{ential expressed}\\ \text{in ¢/gal}\end{array}\right]\left[\begin{array}{c}\text{Percentage of}\\ \text{Cost with Catalytic}\\ \text{Converter}\end{array}\right]}{[\text{MPG of model year under consideration (100 ¢/\$)}]}$$

EXHIBIT 3.3

EFFECT OF POLLUTION CONTROL DEVICES ON FUEL CONSUMPTION

Measure	**Effect on Fuel Consumption**
Retarded Spark Timing	negative
Rich Air/Fuel Ratio	negative
Port Exhaust Gas Recirculation	negative
Lowered Compression Ratio	negative
Quick Heat Manifold	positive
Lean Air/Fuel Ratio	positive
Heated Intake Air	positive
Catalytic Converters	neutral

Source: Tradeoffs Associated with Possible Emissions Standards, U.S. Environmental Protection Agency, February 1975.

The unleaded differential penalty costs, on the other hand, are affected by the size of the fuel consumption penalty. An alternative way of calculating the fuel consumption penalty and the unleaded differential costs is to have the fuel consumption penalty costs affected by the unleaded differential, but the unleaded differential costs not be affected by the size of the fuel consumption penalty.

A simple example, presented in Exhibit 3.4, illustrates the differences between the methods. The method used in this study calculates the fuel consumption penalty costs with the price of regular gas, so that the costs of unleaded gasoline and hence the differential do not affect the results. This represents the "pure" fuel consumption penalty costs. However, the method calculates the unleaded price penalty costs with the current model year's miles per gallon (MPG), so that any increase in MPG, and hence any fuel consumption benefit or penalty, would affect the results.

The alternative method calculates the fuel consumption penalty costs using the price of unleaded gasoline. Thus, the unleaded price differential will affect the results. The unleaded price differential, however, is calculated using the base year's MPG, so that any changes in fuel consumption do not affect the results. Therefore, this would be the "pure" unleaded price penalty costs. As Exhibit 3.4 shows, both methods yield the same overall costs of the fuel consumption penalty plus unleaded price differential.

EXHIBIT 3.4

EXAMPLE OF FUEL CONSUMPTION AND UNLEADED PRICE PENALTY CALCULATIONS

	Fuel Consumption Penalty	Unleaded Price Penalty	Total Penalty
Method Used in this Study	$\frac{(10\%)(50¢/gal)(100{,}000 \text{ miles})}{18 \text{ MPG}} = \$278$ a/	$\frac{(1¢/gal)(100{,}000 \text{ miles})}{18 \text{ MPG}} = \$55$	$333
Alternative Method	$\frac{(10\%)(51¢/gal)(100{,}000 \text{ miles})}{18 \text{ MPG}} = \$283$	$\frac{(1¢/gal)(100{,}000 \text{ miles})}{20 \text{ MPG}} = \$50$ b/	$333

Assumptions:
10% Fuel Consumption Penalty, based on an increase in consumption from 20 mpg to 18 mpg.
1~/gal unleaded price differential
50~/gal gasoline price
100,000 miles lifetime mileage

a/$278 represents the fuel consumption penalty costs independent of the unleaded price differential effects.

b/$50 represents the unleaded differential costs independent of the fuel consumption penalty effects.

One final point should be made regarding the fuel penalty. EPA has promulgated certain regulations requiring that the lead content of regular gasoline be reduced (lead phase-down). The purpose of these lead phase-down regulations is to reduce the emissions of lead particles. They have nothing to do with protecting the catalytic converter's ability to control gaseous emissions. Therefore, costs incurred by the petroleum industry to meet lead phase-down requirements should not be attributed to emissions control regulations. None of the cost estimates we examined explicitly addressed this problem or indicated that lead phase-down costs were not improperly attributed to emissions control regulations.

3.3 Cost Estimates Summary

The standardized estimates of total costs to consumers in 1967 dollars associated with automobile emissions control regulations are summarized in Exhibit 3.5 and graphically presented in Exhibit 3.6.

EXHIBIT 3.5

TOTAL COSTS (BENEFITS) TO CONSUMERS
(1967$)

Model Year	Standard	STUDY									Mean	Standard Deviation	Coeff. of Var.	Difference Between First & Last Estimate
		CC69	EC71	EC72	CC74	NAS74	DR76	5A77	3A77	CC79				
1970	3.9/33.3/-	33	(60)	63	293	--	--	--	--	333	133	172	129%	+300
1972	3.4/39/-	--	(35)	349	407	--	--	--	--	455	294	223	76%	+490
1973	3.4/39/3.0	--	87	492	550	556	--	--	--	571	453	207	46%	+484
1975	1.5/15/3.1	--	--	--	418	162	--	--	--	128	236	189	77%	-290
1977	1.5/15/2.0	--	--	--	--	--	--	--	--	125	N/A	N/A	N/A	N/A
1980	.41/7.0/2.0	--	--	--	--	--	--	--	198	288	228	N/A	N/A	+90
1981	.41/3.4/1.0	--	--	--	--	249	423	391	310	351	345	68	20%	+102

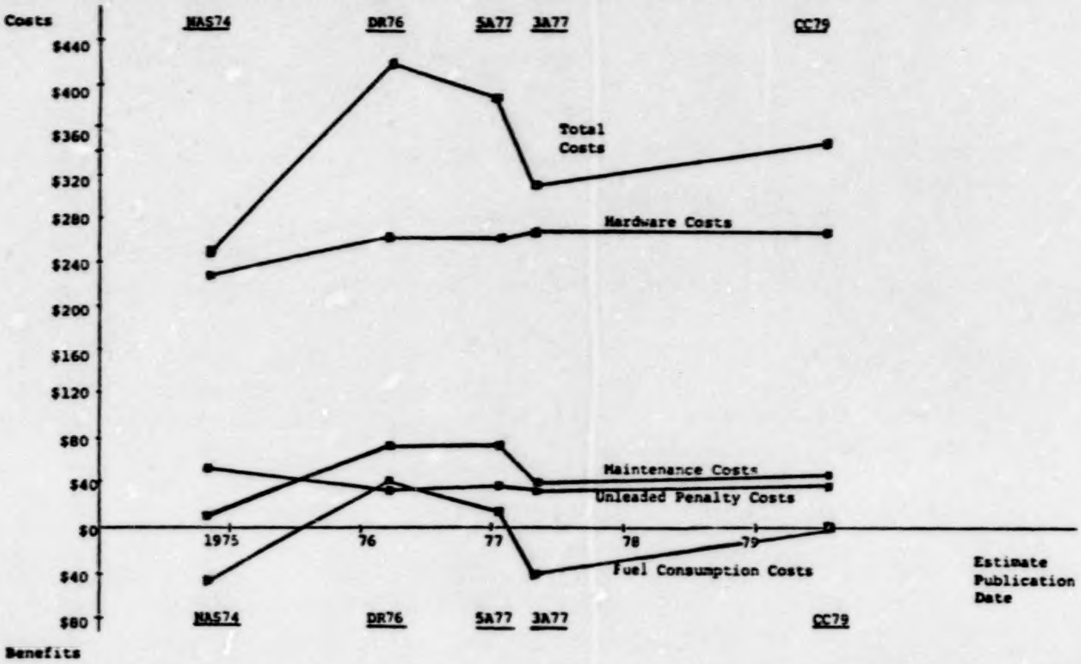
With the exception of the 1975 model year standard, there is a dramatic increase in the cost estimates from the first estimate to the last estimate. This increase usually represents a consistent upward trend in the revision of cost estimates.

For model year 1981 there is a slight downward trend after a sharp increase from the NAS74 estimate to the DR76 estimate. For the 1970, 1971, and 1972 model year standards there appear to be consistent inital upward revisions from the EC71 estimates to the EC72 estimates with a continuing moderate rise in costs through the recent studies. However, to understand the changes in overall costs, the components of the total cost estimates (hardware, maintenance, fuel penalty, and unleaded price penalty) must be examined.

The total cost estimates presented in Exhibit 3.5 and the components of total cost estimates for model year 1980 are graphically presented in Exhibit 3.6. Graphic presentations of standardized costs are presented in Appendix C for model years 1970, 1972, 1973, 1975, 1977, and 1980. This exhibit and the exhibits in Appendix C seem to indicate that while there is little variation in the costs associated with hardware and the unleaded gas costs, the costs associated with the fuel consumption penalty and maintenance costs vary considerably.

EXHIBIT 3.6

TOTAL COST ESTIMATES AND COMPONENTS OF TOTAL COST ESTIMATES FOR THE 1970, 1972, 1973, 1975, 1980 AND 1981 MODEL YEARS BY STUDY



The early, or pre-EC72 studies, uniformly estimated low fuel consumption penalty and maintenance costs. After EC72 there continues to be considerable variation among the estimates for these cost components. For example, fuel consumption penalty estimates for the 1981 model year standard vary from a penalty of $50 (NAS74) to a savings of $44 (3A77) with a mean of a $7 penalty and a standard deviation of $40. Maintenance cost estimates vary from a low of $8 per year (NAS)74 to a high of $78 per year (DR76 and 5A77). The following section examines the assumptions and methods used to estimate these costs to identify why this variation may have occurred.

3.4 Analysis of Cost Estimation Methodologies and Assumptions

To understand the cost estimates of a pollution control standard requires that one has a clear idea of the assumptions and methodologies that were employed to derive those costs. The purpose of this section is to provide this understanding by examining the assumptions and methodologies employed by the nine studies examined. In some instances we were not able to determine the methodologies employed, even after conversation with the authors and analysts responsible for their preparation. In these instances, we reconstructed the methods, where possible, in consultation with the original authors.

The problems with past cost estimation studies can be grouped into three categories, (1) omission of cost components, (2) inadequate documentation, and (3) methodological problems. These three categories are discussed below.

3.4.1 Omission of Cost Components

All four cost components--hardware costs, fuel penalty costs, maintenance costs, and unleaded price penalty costs--are critical parts of the total costs of emissions control regulations. Omission of any one of these components renders a cost analysis incomplete. Four of the nine studies examined here left out one component of the costs; none left out more than one.

Hardware Costs: Every study examined presents some form of hardware cost information.

Maintenance Costs: Every study examined presents some form of maintenance cost information.

Fuel Consumption Penalty Costs: One of the nine studies, CC69, presents no estimate of the fuel consumption penalty costs.

Unleaded Price Penalty Costs: Only six of the nine studies estimate the costs of catalytic converter based pollution control systems. Of these six, half do not estimate the unleaded price penalty (3A77, 5A77, DR76).

3.4.2 Inadequate Documentation

The value of a cost analysis fades rapidly after its publication unless three criteria are satisfied: (1) cost estimates are reproducible, based on the input data, (2) cost estimates are comparable with estimates presented in other studies, and (3) cost estimates are easily revised using alternative assumptions.

Without proper documentation, none of the above criteria can be satisfied. Every one of the nine studies examined failed to document in an adequate fashion one or more critical input assumptions. We will not provide here an exhaustive catalogue of what each study neglected to describe. Instead, the more important omissions committed by one or more studies will be discussed below.

3.4.2.1 General Assumptions. This section describes omissions by various studies of the documentation of critical general assumptions. The assumptions omitted are frequently so critical to the cost estimates that it becomes nearly impossible to analyze the variances of cost components among the studies examined.

Price level index. The price level index of all costs must be specified, or the cost estimates are meaningless. If costs are borrowed from previous studies, the analyst must be careful to adjust these costs to the price level of the current study. One study, CC74, was a particularly egregious violator of this rule. The introduction of CC74 states that all costs were in 1973 dollars. However, the table of hardware costs in CC74 was identical to a table in an earlier report, EC72, whose costs were in 1970 dollars. This same table in CC74 was also virtually identical to another table in CC79, a later report, that apparently used nominal dollars. Therefore, it is not clear whether the hardware costs are in 1973, 1970, or nominal dollars. Including CC74, four of nine studies did not clearly specify price indices (CC69, 3A77, CC79).

Vehicle lifetime mileage. The lifetime mileage of a car is an essential input to the calculation of the lifetime costs of the unleaded price and fuel consumption penalties, and in certain instances, for maintenance costs. Five of the nine studies, CC69, EC72, CC74, 3A77, CC79, did not give an estimate of the vehicles' lifetime mileage.

Discount factor. The selection of discount factors makes a difference in the relative importance of hardware costs, or "first" costs, versus the maintenance, fuel penalty, and unleaded price penalty costs which are incurred in the future. Obviously, the higher the discount factor, the less important future costs are than present costs. Although it is not specified in the texts of the nine studies, the real discount factor used in the studies seems to be zero.

Price and grade of gasoline. The present and future price of gasoline assumed by a study makes a large difference in the lifetime fuel consumption penalty calculations. Of course, the grade(s) of gasoline that is assumed to be consumed now and in the future should also be specified, because the price of gasoline is related to the grade of gasoline. Three out of the eight applicable studies, CC74, 3A77, and CC79, did not estimate the price of gasoline. Only two out of the five studies, CC71, and NAS74, that estimate the price of gasoline specify what grade of gasoline was to be used.

3.4.2.2 Hardware Costs Assumptions. This section describes omissions in the documentation provided by various studies of critical hardware costs assumptions.

Itemization of costs. Hardware component costs are frequently not individually identified. Of the nine studies considered here, only five completely itemize hardware costs (CC69, CC74, 3A77, 5A77, DR76), and only two (DR76, 5A77) completely itemize maintenance costs.

Location on the learning curve. If hardware costs are derived using the retail price equivalent method (see the following section for a definition of the actual price method), then the position of the manufacturers on their learning curve should be specified. Learning curve effects refer to the decreases in costs of production due to increased production efficiencies resulting from learning about the production process. For example, if the first million catalytic converters cost $100 each to build, the next million may only cost $80 each. Only NAS74 addresses learning curve effects.

Fixed Cost Amortization. R&D expenses, tooling expenditures, and certain labor costs are among the fixed costs of producing pollution control hardware. These fixed costs are amortized over a sales base determined by the companies. No studies indicate assumptions concerning the sales base over which fixed costs are amortized. This is a critical factor because as the sales base increases or decreases, unit costs associated with emissions controls either increase or decrease.

Fixed and variable costs. If costs are not derived using the actual price method, then the fixed and variable components of hardware costs should be identified. None of the studies examined provides estimates for fixed and variable costs.

Equipment for Evaporative Emission Control. Five of the nine studies did not separately itemize the costs of evaporative and exhaust emissions controls (EC72, NAS74, DR76, 5A77, 3A77). All equipment and maintenance procedures required for evaporative as well as emissions controls should be identified. This allows analysts to determine separately the costs of exhausts emissions controls.

Equipment for Crankcase Blowby Emissions Control. The control of crankcase emissions was required on a national basis in 1968, long before the passage of the Clean Air Act of 1970, but the costs of crankcase controls are often included with the costs of exhaust emissions controls. The data necessary to isolate these crankcase control costs from other costs is provided in only two of the studies examined (CC74 and CC79).

3.4.2.3 Maintenance Costs Assumptions. This section describes omissions in the documentation provided by various studies of critical maintenance cost assumptions.

Itemization of costs. Hardware component installation and maintenance costs are frequently not individually identified. Of the nine studies considered here, only five itemize hardware costs (CC69, CC74, 3A77, 5A77, DR76), and only two (DR76, 5A77) completely itemize maintenance costs.

Maintenance schedule. Two of the nine studies, 3A77, and CC77, have inadequate maintenance schedule documentation. A critical component of lifetime maintenance costs is the schedule of required maintenance tasks. If a fairly detailed schedule of maintenance tasks is not available, it is difficult to compare the maintenance costs estimates.

Labor costs. None of the studies examined specifies the parts and labor costs. Without specification of these costs, comparisons among studies are difficult.

3.4.2.4 Fuel Consumption Penalty Costs Assumptions. This section describes omissions in the documentation of critical fuel consumption penalty costs assumptions.

Fuel consumption data. Only three of the studies examined indicate the fuel consumption of the baseline vehicles and the vehicles affected by the standard under consideration (3A77, CC74, CC79). Without these data, it is not possible to isolate the substantive differences between the studies' estimates of fuel consumption penalty costs.

Method of measuring fuel consumption. Of the five studies that provide any fuel consumption data, only two, DR76 and 5A77, specified the method used to measure fuel consumption. Fuel consumption can be tested on a chassis dynanometer, such as the EPA Urban and Highway cycle tests, or in actual road use. Because pollution control equipment may affect fuel consumption differently, depending on the fuel consumption test used, it is critical that the method of measurement be specified.

Vehicle weight. Vehicle weight affects fuel consumption; in general, the heavier a car, the more fuel it consumes. Therefore, the weight of the vehicle or fleet of vehicles under consideration is critical to an understanding of cost estimates for fuel consumption penalties. Of the five studies that furnish fuel consumption data, only three, DR76, 3A77, and 5A77, specify the vehicle or average fleet weights.

Baseline Vehicle or Fleet MPG. In three out of the eight applicable studies, CC74, 3A77, and CC79, the fuel penalties are presented as a simple numerical or percentage increase (or decrease) in fuel consumption per mile. Unfortunately, this alone does not provide the information necessary to calculate the lifetime dollar costs of the fuel penalty. It is also necessary to know the baseline fuel consumption that the increase is applied to. As the example in Exhibit 3.7 illustrates, the same penalty (4 percent or 2 MPG) applied to different baselines (15 or 25 MPG) results in different costs. This example assumes a useful vehicle life of 100,000 miles and a fuel price of 50¢ per gallon in 1967$.

EXHIBIT 3.7

EXAMPLE OF FUEL CONSUMPTION PENALTY COST ESTIMATES
USING ALTERNATIVE FUEL ECONOMY BASELINES

Energy Consumption Baseline	4% Penalty	2 MPG Penalty
15 MPG	$133	$513
25 MPG	$80	$174

Assumptions: Vehicle life of 100,000 miles and fuel price of 50¢ per gallon in 1967 dollars.

3.4.2.5 Unleaded Price Penalty Costs Assumptions. This section describes omissions in the documentation of critical unleaded price penalty costs assumptions.

Only two studies provide information on the components of the unleaded price penalty costs (CC74 and NAS74). These components include the refinery cost

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differential, the distribution cost differential, and the "third pump" cost differential, which represents the components of the unleaded penalty costs estimates.

3.4.3 Methodological Problems

This section examines the problems we have identified with the cost estimation methodologies employed by the nine studies. A variety of valid methodologies can be employed to estimate the costs of regulation. What is important is not the choice of the "best" methodology but the ability of policymakers to understand the effect of each alternative cost accounting method on the cost estimate.

3.4.3.1 Hardware Costs--Actual versus Retail Price Equivalent. Two distinct methodologies are employed by the nine studies to develop hardware cost estimates. The first, employed by 3A77 is the actual price method. It attempts to estimate the actual retail price the consumer pays for pollution control equipment and modifications. The second is the retail price equivalent method, which attempts to estimate the costs of pollution control to the manufacturer, and applies a standard markup to reach a retail price equivalent. There is a profound difference, at least in theory, between these two methods. These differences are discussed below.

The actual price to the consumer for pollution control hardware in any given model year is not necessarily the same as the cost of pollution controls to the manufacturer (plus a standard profit markup). The eventual cost passed through to the customer is affected by many factors related to a firm's marketing policy or ability to pass on product price increases to consumers. Firms may choose to pass on to consumers different fractions of the costs associated with emission control devices.

Retail price equivalents are the costs to the manufacturer of making the modifications and additions to the cars necessary to meet the emissions standards, plus a normal markup percentage. The estimates of manufacturing cost are obtained from submissions by manufacturers to the EPA, or from engineering study estimates of the costs of an emissions control system. A markup factor is then applied to the manufacturing costs to obtain the retail price equivalent. Earlier industry studies, sensitive to the public's feeling that manufacturers should not make a profit from pollution control equipment, tended to use low or zero markup factors, while later industry studies recognized that the cost of pollution controls was no different from the cost of any other automobile component, and used a standard markup. A simple example may help to illustrate the differences between retail price equivalents and actual costs.

For model year 1977, the California emission standard was .41/9.0/1.5 while the Federal standard was 1.5/15/2.0. Because the California standard was stricter than the Federal 49-State standard, a car meeting the California standards was probably more expensive to manufacture than a 49-state car. However, depending on the marketing strategy of the manufacturer, the extra costs of the California car could have been passed on to the consumer in at least three ways: (1) all of the extra costs could be included in the sticker price of cars sold in California, (2) all the costs could be included in the sticker price of all cars sold in the United States, or (3) there could have been a partial allocation between California and 49-State cars. In the last two cases, the purchaser of cars outside of California would be subsidizing the costs of producing cars purchased and used in California. Under the retail price equivalent method, these different allocation methods would not be reflected in the hardware cost estimates. However, under the actual price method, the retail price would reflect marketing-related pricing decisions made by the manufacturer.

3.4.3.2 Hardware Costs--Industry Data. Hardware costs submitted by industry to EPA for the calculation of retail price equivalents are of uncertain value. The accounting systems in use by the four domestic automobile manufacturers do not necessarily capture the actual production costs of a given piece of hardware.

In general, costs generated by industry cost accounting systems are dependent on decisions made about capital investment writeoff periods, joint product cost overhead allocation, and material prices. These decisions are not made consistently from company to company, or even within one company over time. Costs are developed to serve many purposes: to predict economic effects of decisions, to determine income and asset valuations, to establish managerial goals, and, of course, to submit to regulatory agencies. The costs for the same item supplied to the Government by two different manufacturers are not necessarily comparable. Because the details of an accounting system of a private firm are not open to public scrutiny, it is not possible to standardize the costs generated by the individual firm's accounting systems. In personal conversations with the financial staff of two automobile manufacturers, this lack of comparability was confirmed among cost estimates provided by different manufacturers.

Many of the earlier EPA studies depended on industry submission of cost data. It is safe to say that very few firms have set up their accounting systems so that the cost data produced are optimal for evaluating the costs of pollution control. EPA has recognized this problem, and contracted for the development of a cost accounting system of general applicability, including a full documentation of all allocation decisions.[10]

Another problem with industry supplied data is that the costs to the firm of manufacturing pollution control devices, as the costs of manufacturing any other parts, are considered confidential information by the automobile industry. Manufacturers argue (with good reason) that this type of information would be very useful to competitors in formulating their pricing policies. The net effect, however, is that cost information supplied by industry available to the public tends to lack detail, be highly aggregated, and have a good deal of imprecision. For example, the Bureau of Labor Statistics (BLS) has access to confidential cost information of the automobile producers; most likely this information is provided with a high level of detail. Unfortunately, to preserve the confidentiality of the data, the BLS publications (Report on Quality Changes for New Model Passenger Cars) will only report the data at a very high level of aggregation.

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[10] Cost Estimates for Emission Control Related Components/ Systems and Cost Methodology Description, Rath and Strong Inc., March, 1978.

3.4.3.3 *Fuel Consumption Penalty Costs--Vehicle Weight* The weight of the car has a profound effect on fuel economy. In general, the heavier the car, the more fuel it consumes. For a 100-pound increase in vehicle weight, the average motorist can expect fuel efficiency (during city driving) to decrease by about 0.2 MPG.[11] The weight related fuel economy effects are greater for smaller cars than for larger cars, but in general, for a car that normally gets 20 MPG, a 100-pound increase in weight will increase the lifetime costs of the car about $50 (1967$).

As a rule, the larger the car, the more gasoline it consumes and, hence, the more grams per mile of pollutants (particularly NOx) need to be controlled. If the pollution control techniques impose a fuel penalty for the average weight car, it follows that heavy cars with more equipment would have a more severe penalty.

The weight mix of the new car fleet has changed significantly from the 1968 model year to model year 1980, as can be seen in Exhibit 3.8. Cars became progressively heavier from the precontrol years to model year 1975, and have since become lighter. Care must be taken not to allow increasing weight trends to bias fuel penalty calculations upwards, and decreasing weight trends to bias fuel penalty calculations downwards.

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[11] *"Drive More, Pay Less,"* Chrysler Corporation Press release of May 24, 1973.

EXHIBIT 3.8

CHANGE IN AUTOMOBILE WEIGHT OVER TIME, PRECONTROL MODEL YEAR TO 1980 MODEL YEAR

Gross Vehicle Weight	Percent of New Car Fleet			
	Precontrol	MY 70	MY 75	MY 80 a/
4,500 lbs and over	27.2	40.4	50.1	7.6
3,000 to 4,499 lbs	63.1	42.5	35.7	62.7
2,000 to 2,999 lbs	9.7	17.1	14.1	29.5

a/ 1980 fleet weight mix was estimated.
Source: Murrell, J.D. et al., Passenger Car and Light Truck Fuel Economy Trends Through 1980, SAE # 800853, June 1980.

The EPA has developed a simple methodology to isolate the weight effects on fuel penalty; unfortunately it has not been used, as far as can be determined, in any of the studies examined here. This methodology is illustrated in Exhibit 3.9.

EXHIBIT 3.9

METHODOLOGY OF ISOLATING THE EFFECTS OF WEIGHT ON THE FUEL PENALTY

	Base Model Year Fleet			Current Model Year Fleet				
	Gross Vehicle Weight	Sales Fraction	MPG	Gross Vehicle Weight	Sales Fraction	MPG	Fuel Penalty Decrease in MPG from the Base Model Year Fleet to the Current Model Year Fleet	Fuel Penalty Cost Estimate (lifetime costs)
	2,000 3,000 4,000 5,000	10% 30% 40% 20%	24.0 22.0 20.0 18.0	2,000 3,000 4,000 5,000	15% 35% 40% 10%	29.0 22.0 17.0 14.0		
Sales Weighted Average	3,700	---	20.4	3,450	---	19.1	6.4%	$167
Sales Weighted Average at Current Model Year Sales Fractions	3,450	---	21.0	3,450	---	19.1	9.1%	$237
Difference							2.7%	$70

The sales weighted average MPG[12] is developed for the current year model fleet. But to eliminate the effects of the shift in weight mix, the base fleet weight classes are weighted by the current model year sales, instead of the base model year sales.

As Exhibit 3.9 shows, if the base model year fleet had not been properly weighted at current sales fractions, the fuel penalty would have been underestimated by more than two percentage points (6.4% instead of 9.1%), translating into a $70 difference in lifetime costs.

Of the eight studies that calculate a fuel penalty, all attempt in some fashion to isolate the effects of vehicle weight on fuel economy from the fuel penalty. However, some of the methodologies employed are of questionable validity. Two studies, DR76 and 5A77, look at a modified adjustment of the fuel penalty of a 4,000 pound car. The fuel penalty of a 4,000 pound car is not the same as the average fuel penalty of a sales weighted fleet, even a fleet with an average weight of 4,000 pounds. In fact, a study by EPA[13] has shown that looking at one weight of cars can be profoundly misleading. In some instances, heavier cars have experienced decreased fuel economy while lighter cars of the same year experienced increased fuel economy.

The methodologies apprently used in the studies to calculate the fuel penalties are very different; even if the same fuel consumption figures are used to calculate fuel consumption penalties, each study would derive quite different fuel consumption penalty estimates. Unfortunately, none of the studies used the same fuel economy data, and furthermore none of the studies furnishes or cites unambiguously the fuel consumption figures that were used in the fuel consumption calculations, so that a precise analysis of variance between the fuel penalty estimates of the five studies is not possible.

What can be shown, however, is that given exactly the same fuel consumption and sales figures, each study's methodology would give a different result. The following simplified example illustrated in Exhibit 3.10 shows this, using hypothetical but realistic fuel economy and sales assumptions.

Four studies, NAS74, DR76, 5A77, and CC79, are included in this example. The mileage and sales fraction data are the same as those shown in Exhibit 3.9. The NAS74 method simply calculates the percentage change in fuel economy from the base year to the current year of a certain size car, in this hypothetical example a 4,000 lb. car.[14]. No other adjustments are made.

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[12] Actually the sales-weighted fuel consumption (gallons per mile-GPM) is calculated, and then converted to MPG.

[13] A Report on Automotive Fuel Economy, p. 9, table 3, U.S. Environmental Protection Agency, February 1974.

[14] The NAS method did not actually estimate the fuel penalty of the 4,000-lb. car, but rather the fuel penalty of a 6-cylinder intermediate size domestic model car. At the time NAS wrote their study, 6-cylinder cars weighed from 2,700 lbs (Gremlin) to 4,000 lbs (Bel Air), with the typical car about 3,500 lbs. WARDS Automotive Yearbook, 1973, p. 204-205.

EXHIBIT 3.10

FUEL CONSUMPTION PENALTY METHODOLOGY USED BY FOUR STUDIES

	Methodology Employed by NAS74	Methodology Employed by DR76 and 5A77	Methodology Employed CC79
Fuel Penalty	$\frac{\text{MPG 4,000, current} - \text{MPG 4,000, base}}{\text{MPG 4,000, base}}$ $\frac{17.0 - 20.0}{20.0} = -15\%$	$\frac{\text{MPG 4,000, current} - \text{MPG 4,000, base}}{\text{MPG 4,000, base}} \times \frac{\text{S.W. Average Weight*}}{4{,}000}$ $\frac{17.0 - 20.0}{20.0} \times \frac{3{,}450}{4{,}000} = -12.9\%$	$\frac{\text{SWMPG current} -^{**} \text{SWMPG base, at current weight}}{\text{SWMPG base, at current weight}}$ $\frac{19.1 - 21.0}{21.0} = -9.0\%$
	15% Fuel Penalty	12.9% Fuel Penalty	9.0% Fuel Penalty
Fuel Penalty Cost	$\frac{(15\%\ \text{F.P.})(50¢./\text{gal})(10^5\ \text{mi.})}{17.0\ \text{MPG}}$	$\frac{(12.9\%\ \text{F.P.})(50¢/\text{Gal})(10^5\ \text{mi.})}{17.0\ \text{MPGPT}}$	$\frac{(9.0\%\ \text{F.P.})(50¢/\text{gal})(10^5\ \text{mi.})}{19.1\ \text{MPG}}$
	$441	$379	$235

*Sales weighted average weight.
**Sales weighted MPG.

The DR76 and 5A77 technique takes the fuel penalty of one weight class of car, 4,000 pounds in this example, and adjusts the fuel penalty for this vehicle by multiplying it by the ratio of the current model year sales weighted average fleet weight (in this example 3,450) and the vehicle's weight of 4,000 lbs. CC79 is believed to use a very different method of fuel penalty calculation, which divides the current model year sales weighted average MPG by the base year average MPG, weighted at the current model years sales weight fractions.

The differences between the three methods, using the same data, can be very significant, as illustrated in Exhibit 3.10. From the same data, the NAS74 method calculated a fuel penalty of $441, which is 16 percent greater than the fuel penalty of $379 based on the DR76/5A77 technique and 87 percent greater than the $235 penalty based on the CC79 technique.

3.4.3.4 Unleaded Price Differential Costs. The costs of making unleaded (not low-lead) gasoline are incurred solely to allow use of catalytic converters as a viable pollution control measure. Therefore, the unleaded differential represents an integral part of the costs of pollution control.

However, unlike hardware costs, fuel penalty costs, and maintenance costs, the unleaded price differential is directly influenced by other Government regulations, specifically DOE price regulations. The two latest EPA studies CC74, CC79, attempt to isolate the effects of DOE price regulations by ignoring the actual retail differential between unleaded and leaded gasoline.

Instead, they estimate (or based their estimates on) the total national costs of manufacturing and marketing unleaded gasoline over a fixed period, and divided these national costs by the amount of gallons sold during that same period. This method of estimating the unleaded price differential is entirely analogous to the retail price equivalent method of estimating hardware costs.

EPA's method of compensating for DOE price regulations might be unnecessary and even biased, because the actual retail differential historically has been substantially greater than EPA's differential in price between unleaded and leaded gasoline, so as to discourage "fuel switching" (the use of leaded gasoline in cars equipped with catalytic converters). Hence, it would seem that the actual unleaded differential would have been even higher in the absence of DOE price regulations. Apparently, retail marketing considerations have caused the profit margin on unleaded gasoline to be greater than for leaded gasoline.

3.4.3.5 Maintenance Costs. Two distinct methods of looking at maintenance costs have evolved. The first, used by NAS74, is to include all scheduled maintenance activities that are required to keep a vehicle in compliance with the emissions standards. This means that such routine activities as spark plug changes and oil changes are included. The second method only includes incremental maintenance costs made necessary by the standards. Therefore, meintenance routines required to keep a car's emissions low, but that were already being performed before the standard went into effect, would not be included. This is the method used by EC69, EC71, EC72, DR76, 3A77, and 5A77.[15] The first method would appear to include costs that should properly be included in the baseline. Quite simply, there is no reason to charge a cost to a regulation, if the cost was being regularly incurred before the regulation was in effect.

3.4.3.6 Other--Double Counting. None of the studies examined allocates regulatory costs for specific vehicle modifications to more than one regulation. This may be necessary where vehicle modifications may be attributable to more than one regulation. If costs are not distributed among the appropriate regulations, double counting of costs will occur.

The methodology of allocating costs incurred by industry in meeting more than one regulation, or to satisfy the desires of the marketplace, presents a difficult problem in analyzing the costs of the regulation. An interesting example is the Electronic Control Module (ECM) on model year 1981 cars, critical for the optimal operation of the three-way catalyst (TWC). However, the ECM also increases the fuel economy of the car, and would be used on certain large models even if not needed to meet the exhaust emissions standards. It is difficult to determine what percentage of the ECM costs should be allocated to emissions control regulations, fuel economy regulations, and the demand by the consumer for better fuel economy. In the studies we examined, the full cost of the ECM (and other hardware devices with uses other than pollution control) is charged to pollution control. This simple, conservative allocation scheme for pollution control costs can cause problems if it is followed for regulatory cost estimates for other regulations. The full amount of the ECM (or other hardware items) could be counted twice, once for pollution control regulations and once for fuel economy regulations. EPA has begun to make adjustments in its regulatory analyses to address this problem.

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[15] It is not clear how CC74 and CC79 treat maintenance costs.

We note here that simultaneously meeting more than one related regulation may not always result in cost savings. In fact, the sum of regulatory compliance costs for each related regulation may be less than compliance costs of meeting all the regulations simultaneously. This would occur if the compliance costs of each regulation are increased due to requirements imposed by other regulations.

4.0 Costs of EPA and DOT Motor Vehicle Regulations

4.1 Overview

This section briefly examines the consistency and adequacy of regulatory cost analyses prepared by EPA for a variety of mobile source emissions control regulations and by DOT for a variety of truck and automobile safety and fuel economy regulations. The regulatory proposals considered in this section of the report are listed in Appendix D. The previous section identified several problems that limit the usefulness of cost estimates prepared since 1967 for EPA automobile emissions control regulations. This section attempts to show that these problems are not unique to cost estimates for EPA automobile emissions control regulations. Rather they also apply to many cost estimates for EPA and DOT regulations.

Our analysis is limited to cost estimates for 50 pending[16] regulatory proposals, of which 28 were at the NPRM stage, prepared by DOT and EPA and provided to the U.S. Regulatory Council as of January 1981. These estimates were used by the Regulatory Council to prepare the *Automobile Calendar*[17] and a report on the status of regulatory analyses.[18] Three of these fifty regulatory proposals considered here amend the automobile emissions control regulations reviewed in the preceding section.

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[16] Regulations which would have had a future effect or impact on the manufacture, sale, or use of automobiles, light duty trucks, and, in some cases, heavy duty trucks as of January 1, 1981.

[17] *The Automobile Calendar: Recent and Pending Activities Affecting Motor Vehicles*, prepared by ICF Inc. for the U.S. Regulatory Council, "Criteria for Selection and Calendar Scope," January 1981.

[18] *Assessing Regulatory Impacts: The Federal Experience with the Auto Industry*, prepared by ICF Inc. for the U.S. Regulatory Council, March 1981.

4.2 Availability of Cost Estimates

Complete cost estimates and detailed analyses are not available for most of the EPA mobile source and DOT safety and fuel economy regulatory proposals. In fact, for the 50 regulatory proposals examined, "fairly complete" information was available for only 17 regulatory proposals. For the purposes of this paper, fairly complete cost information includes unit and aggregate costs to consumers and manufacturers. Of the 28 of the proposals that had reached the Notice of Proposed Rulemaking stage (NPRM), fairly complete information was available for 14, or 50 percent, of the proposals. Two of these were for automobile emissions control regulations. The results of our review are presented in Exhibit 4.1. No cost information is available for four, or 14 percent, of the regulatory proposals. Therefore, we discovered that comprehensive cost information had not been routinely identified for either the DOT or EPA mobile source regulatory proposals we examined.

EXHIBIT 4.1

AVAILABILITY OF COST INFORMATION FOR
EPA AND DOT REGULATORY PROPOSALS AS OF JANUARY 1981

	Total		Fairly Complete a/		Limited b/		Not Available	
	No.	%	No.	%	No.	%	No.	%
EPA	21	100	7	33 c/	6	29	8	38
DOT	29	100	10	34 d/	6	21	13	45
TOTAL	50	100	17	34	12	24	21	42

a/ Fairly complete cost information includes unit and aggregate costs to consumers and manufacturers.

b/ Limited cost information implies that at least one piece of cost data is available but not the items necessary to meet the fairly complete definition.

c/ One of these regulations is not expected to generate any costs.

d/ The regulatory analyses for two of these regulations specify that they are not expected to generate any costs.

4.3 Status of Cost Estimates

Although fairly complete cost information is available for 34 percent of the DOT and EPA regulatory proposals we have examined (50 percent if only NPRM proposals are considered), we have identified methodological problems or inconsistencies among the analyses that provide fairly complete information and the analyses of proposals for which partial data are available. We found that these problems make it nearly impossible for policy officials to compare the costs of each regulatory proposal or to assess the cumulative effect of the combined proposals on the automobile industry, consumers, and the economy. This section describes the methodological problems we have identified for: (1) manufacturers' costs estimates, (2) consumers' costs estimates and (3) assumptions affecting both manufacturers' and consumers' costs estimates.

4.3.1 Manufacturers' Costs Estimates

4.3.1.1 Manufacturing Costs Components. Estimates of manufacturers' costs are not available for 23 of the 50 cost estimates we examined, as can be seen in Exhibit 4.2. Manufacturers' costs estimates are provided for 27 regulations.

EXHIBIT 4.2

SUMMARY OF AVAILABILITY OF MANUFACTURERS' COST ESTIMATES

Number of Regulatory Proposals Examined		
Formal Proposal (NPRM)	28	
Other (pre-NPRM)	22	
Total		50
Number of Regulatory Proposals for which Manufacturers' Aggregate or Unit Costs Estimates are Available		27
Unit Cost Estimates Available		25
Aggregate Cost Estimates Available		
One component	6	
Two or more components	9	
Total		15

For the purposes of this report, we have established five components of manufacturers' costs: R&D, testing, administration, facility modification, and materials and labor (variable costs not passed on to the consumer) required by the regulatory proposal. Fifteen of the 27 cost estimates for which manufacturers' costs are provided identify the costs associated with one or more components of the manufacturing processes. Of the 15 estimates that identify components of the manufacturers' costs, 6 specify the cost of one component and 9 specify the cost of two or more components.

4.3.1.2 Cost Allocations Problems--Double Counting. The manufacturers' costs estimates that are provided are estimated for each regulatory proposal independent of other regulatory proposals. Estimating the costs of a regulatory proposal without considering how producers will adjust their overall manufacturing operations to comply with other, concurrent regulations may result in "double counting" of the costs incurred by manufacturers. Retooling or redesign costs necessary to comply with two or more regulations may overlap. For example, individual regulations requiring the installation of automatic seatbelts and improvements in seatbelt comfort and convenience may be jointly incorporated in manufacturing adjustments. It is likely that manufacturers will adjust current operations in consideration of both regulations at a single time to minimize the capital investments and other costs associated with each regulation. Since no adjustments are identified to offset possible "double counting," the cost estimates associated with a particular proposal may not represent the additional cost solely attributable to that proposal.

4.3.1.3 Consumer Demand. None of the cost estimates examined considers product modifications attributable to consumer demand. All cost estimates are based on the assumption that future product modifications are due solely to regulatory requirements and not to consumer demand. This assumption may significantly contribute to the overestimation of the actual manufacturer's costs which are attributable to regulations where manufacturers may alter product lines partly in response to consumer demand. An example of this is the growing market for small, fuel-efficient vehicles. In such a case, all manufacturer retooling costs necessary to manufacture small fuel-efficient vehicles cannot be attributed to the Federal fuel economy standards, since industry would incur some of these costs regardless of the regulations. In fact, General Motors does not include in its calculations of the costs of Government regulation any of the costs of hardware required to meet Government fuel economy standards, because it believes that the fuel economy improvements were driven by market factors.[19] Another example may be growing consumer demand for safe vehicles due to an awareness of the potentially hazardous effects of unrestrained infant passengers. In such a case, all manufacturer retooling costs necessary to manufacture vehicles with child tether anchorages cannot be attributed to the Federal Child Restraint Systems regulation. Manufacturers may be responding to consumer demand as well as Federal regulation when they decide to install tether anchorages for child restraint systems.

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[19] 1981 General Motors Public Interest Report, General Motors Corporation, p. 36, April 15, 1981.

4.3.1.4 Industry Homogeneity. Among the cost analyses we examined, different assumptions concerning industry homogeneity are used. The assumption of industry homogeneity suggests that each manufacturer experiences similar costs in meeting the standards. Implicit in this assumption is that each manufacturer uses approximately the same technology, has equivalent capacity for vertical integration, and confronts similar economies of scale. Only five EPA and three DOT analyses explicitly address this issue. Each alternatively attempts to estimate the costs incurred by each individual domestic manufacturer. These analyses either use information provided by manufacturers to estimate individual manufacturer capital costs, or weight the average industry cost estimates by historical manufacturer sales information to incorporate the possible impact on smaller, higher cost producers.

4.3.2 Consumer Cost Estimates

The unit (per vehicle) retail price increase for automobiles is the most common piece of cost information provided for the regulatory proposals we examined. Among the 29 EPA and DOT regulatory activities for which some cost information is available, 26 supply data on the estimated unit retail price increases. However, several inconsistent methods are used to develop these estimates. Furthermore, unit cost data are not provided for 24 regulatory proposals. Two consumer cost estimates methodology problems are discussed below.

4.3.2.1 Retail Price Markup Factor. For the majority of the 26 regulatory proposals with consumer cost information, the assumptions concerning retail price markups (how estimated manufacturer costs of compliance are passed on to consumers) are not available. Nine of the 15 regulations for which agency analyses are available provide information on the retail markup assumptions used.

These nine analyses make a number of different assumptions concerning markup factors and how they are applied to the manufacturer's costs. Some analyses estimate only manufacturer's increases, while others include the dealer's margin in the price increase estimates.

Two DOT analyses simply multiply all manufacturer costs by a single markup factor (1.58 and 1.43) to determine consumer costs. The derivation of these markup factors is not explained. The EPA analysis of test procedures for heavy duty vehicle evaporative emission standards applied a 100 percent markup on all control system components and no markup on facility investment or certification costs. Other analyses distinguish between manufacturer and dealer margins. In the DOT analysis of the rearview mirror standard, a 100-percent markup is applied to all manufacturer costs, allocating 75 percent of the markup for the manufacturer sticker price increase and 25 percent for the dealer margin. Three other DOT analyses use a slightly more complex formula, whereby the product of the manufacturer's gross rate of return and the change in capital expenditures is added to the change in variable costs. This total, plus the dealer's margin, equals the retail price increase. Among these three DOT analyses the manufacturer's gross rate of return is estimated at 25 to 27 percent; the dealer's margin is assumed to be 25 percent. In two EPA analyses a total markup of 29 percent was applied to account for the assumed 3-percent dealer profit, 12-percent manufacturer overhead, and 14-percent corporate profit. These latter estimates of corporate overhead and profit were derived by EPA from finaicial information on each corporation provided in Moody's Industrial Manual.

4.3.2.2 Operation and Maintenance Costs. Consumer costs consist of two components--increases in the initial purchase price of the vehicle and Operation and Maintenance (O&M) costs over the useful lifetime of the vehicle. O&M costs refer to the expenses associated with owning and operating a vehicle including the cost of fuel, repairs, and automobile insurance. In general, most EPA and DOT analyses indicated whether or not O&M cost savings or penalties would be incurred. The component of operating cost reductions that received the most attention was fuel savings. This section discusses the estimation procedures used for determining the reductions in fuel costs.

Among the cost estimates we examined, four indicate fuel savings and, to varying degrees of clarity and detail, explain the methodologies and assumptions used in estimating fuel economy benefits. Two other analyses estimate increased fuel costs due to the regulations.

Fuel savings estimates are presented in different units of measurement, which makes the assessment of cumulative fuel economy benefits or the comparison of fuel savings benefits across regulations more difficult. Fuel savings may be presented in dollars or in the amount of fuel (gallons or barrels) saved. Assumptions concerning gasoline prices must be made to convert gallons of gasoline saved into dollars saved. Fuel savings are also presented both on a per vehicle basis or for the entire fleet. To convert these benefits into comparable units, the projected vehicle sales levels must be indicated. Finally, fuel savings are usually presented for the estimated useful life of the vehicle(s), although sometimes annual estimates are provided. The assumptions that must be made explicit to allow the comparison of estimates are not usually provided in the various analyses.

Factors that should be included in the estimation of future fuel consumption savings or costs are the price of gasoline, the useful life of a vehicle, and typical usage pattern (vehicle miles traveled, and sales projections).

Gasoline price assumptions used within various analyses are summarized in Exhibit 4.3. However, the grade or type of gasoline for which prices are identified is not always clearly indicated. Most analyses assume a constant price for gasoline over the lifetime of a vehicle. However, some EPA analyses project real fuel price increases by using a smaller discount factor than the typical 10 percent. The use of a 5 percent discount factor was used in two EPA analyses as a means to approximate the effect of fuel prices rising at an annual rate of 5 percent over and above the general inflation rate.

EXHIBIT 4.3

GASOLINE PRICE ASSUMPTIONS FOR SIX AGENCY ANALYSES WITH ESTIMATES OF FUEL SAVINGS/COSTS

Regulatory Proposal	Gasoline Price Assumption (per gallon)	Calendar Year	Dollar Year	Adjusted Price of Gasoline (in 1980 Calendar Year in 1980 Dollars)(a)	Date of Analysis	Discount Rate	Gasoline Price Inflation Rate
Heavy Duty Evaporative Emission Standards	$1.00	in 1983	in 1980 $	$ .86	1980	10%	5%
Fuel Economy Standards For Model Year 1982 Light Trucks	$1.14(c)	in 1980	in 1979 $	$1.53	1980	10%	3%
HC and CO Gaseous Emission Regulations for 1984 and Later Model Year Heavy-Duty Engines	$1.10(c)	in 1979	in 1979 $	$1.56	1979	10%	5%
Occupant Protection in Interior Tmpacts	$ .80	N/A(b)	in 1979 $	--	1979	10%	5%
Fuel Economy Standards for Model Year 1981-1984 Passenger Cars	$.65-.90	in 1980	in 1977 $	$.96-1.32	1977	10%	0%
Federal Noise Standards for Medium and Heavy Trucks	$ .50(d)	in 1973	in 1973 $	$1.16	1976	10%	0%
Mean:				1.21			
Standard Deviation:				.32			

(a) "Gasoline Price Assumption" was inflated/deflated to the 1980 calendar year using "Gasoline Price Inflation Rate." Prices were converted to 1980 dollars using the July to July increase in the Consumer Price Index for gasoline.

(b) Not available

(c) Price of unleaded gasoline

(d) Price of heavy and medium gasoline for trucks.

If a comparison is made among gasoline price assumptions for 1980 adjusted to 1980 dollars, the prices range from $.86 a gallon to $1.56 a gallon for gasoline (see Exhibit 4.3). One analysis provided a year-by-year projection of variable, increasing gasoline prices. The DOT analysis of model year 1982 light truck fuel economy standards estimated the average price of unleaded gas in 1980 at $1.14/gallon (1979$) based on a 20-percent real price increase over 1979. This price was then adjusted to increase at an annual rate of 3 percent over and above the inflation rate.

The two DOT analyses of fuel economy standards estimated the incremental savings over the current fuel economy standard. A multiplier was used to account for the difference between the EPA estimated MPG and the actual on-road fuel economy. Both analyses assumed the actual on-road fuel economy was 11 percent lower than the EPA estimated. The lifetime savings per vehicle were adjusted for projected production levels of the affected model year vehicles to obtain aggregate fuel savings. In other analyses of fuel savings or costs, the lifetime per vehicle gallon or dollar savings (or cost) due to changes in technology or vehicle weight were usually estimated by agency or industry engineers. The assumptions and methodologies used are not always specified.

4.3.3 Assumptions Affecting Both Manufacturers' Costs and Consumers' Costs Estimates

The demand for new automobiles (sales) affects both the costs and benefits of a regulation. Both total costs and unit costs to manufacturers and consumers depend upon: 1) the cost of manufacturing the affected model vehicles in sufficient numbers to meet consumer demand; and 2) the direct cost of consumers' unwillingness or inability to purchase vehicles at the higher retail prices caused by the regulatory requirements. This section summarizes the assumptions and availability of estimates of sales levels used to estimate costs.

4.3.3.1 Sales Projections. Information on the sales levels used to estimate costs is available for only 16 (32%) of the 50 EPA and DOT regulatory proposals examined. The source or methodology used to estimate sales levels is provided in agency analyses for only 11 of the 16. Although they are critical to many cost estimates, we have not attempted to address here the assumptions used for sales projections by vehicle characteristics including weight and fuel economy. However, inconsistent fleet mix assumptions can be identified among various analyses as well as within components of an individual analysis.[20] The sales projections used to estimate costs are usually developed using the following methods: 1) sales are set equal to a base year; 2) projections are developed using statistical techniques and econometric models; and 3) sales projections are based on estimates supplied by manufacturers.

EPA regulatory analyses typically (that is, four out of six) apply a linear regression technique to historical motor vehicle registration or sales data to predict future years' sales. In some EPA analyses, after linear trends are determined for a general vehicle type, historical manufacturer production ratios are applied to determine the fleet mix (for example gas vs. diesel, or size class). One EPA analysis further modifies this procedure by adjusting historical ratios with intuitive or rational judgments concerning the state of the economy and other Government policy impacts.

Only one agency impact assessment explains the projection of sales through a formal analysis of the determinants of supply and demand. This DOT analysis of fuel economy standards for passenger cars uses an econometric model (the Wharton EFA Motor Vehicle Demand Model) to predict the long-run equilibrium level of automobile demand. Various demographic and economic factors are included in the analysis to describe the relationship of certain variables such as average family size, average age of the population, real income, and scrappage rates with the demand for automobiles. In addition, price elasticity information is used to predict future sales. However, it should be noted that the assumptions used to prepare this analysis in 1977 need to be updated to present accurate estimates given changes in the economic environment and shifts in consumer vehicle demand.

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[20] See ICR Incorporated letter of April 20, 1981 to Department of Transporation; Re: Preliminary Regulatory Evaluation, Amendment to FMVSS No. 208, Safety Belt Comfort and Convenience, Department of Transportation, October 1971.

The various sales projections used in the agency analyses are provided in Appendix B. With two exceptions these sales projections are not consistent. Two two exceptions are EPA analyses of gaseous emissions standards for heavy duty engines and particulate regulations for heavy duty diesel vehicles. Variation in the sales projections are observed for three vehicle types: light duty vehicles, light duty trucks, and heavy duty gasoline-powered vehicles. The sales projections for model year 1982 light duty vehicles range from 10.1 million to 11.8 million, representing a difference of 17 percent. The sales projections for model year 1983 light duty trucks range from 2.5 million to 3.2 million, representing a 30 percent difference. The most significant difference found was in the projections of sales for heavy duty gasoline vehicles. In the EPA analysis of heavy duty evaporative emissions standards and procedures, gasoline-powered heavy duty vehicle sales were estimated to grow at a rate of 1.6 percent; the analysis of gaseous emissions for 1984 and later model year heavy duty engines estimated the sales rate for heavy duty gasoline-powered vehicles to be -2.0 percent for a comparable future time period. It should be noted that the analyses we examined were prepared at different times based on different perceptions of future sales levels.

4.3.3.2 Consumer Response to Prices. Most cost estimates are not based on sales projections that explicitly identify the effect of higher prices on consumer demand. The price increases result in reduced sales and losses to the manufacturers and distributors of automobiles. Most analyses assume that lost sales due to increases in retail prices are negligible.

Sales projection methodologies do not usually make use of supply/demand equilibrium notions. Therefore, manufacturers' and consumers' cost estimates are based on future sales levels that were projected without explicit consideration of the change in demand due to the increases in retail prices. The cost of lost business, if mentioned, is also generally not included in total industry costs. However, many of the analyses we examined indicate that sales lost due to the increase in retail prices are negligible relative to total sales.

For six regulatory activities, estimates of price elasticities (measurements of the change in demand due to change in price) are available. Three analyses of EPA regulations affecting heavy duty and light duty trucks use a demand price elasticity figure based on an equilibrium price/quantity impact model developed for EPA's Office of Noise Abatement Control. The price elasticity of demand for all new trucks was estimated to be in the range of -.9 to -.5; these three analyses used a midrange value of -.7 and assumed this price elasticity of demand for all new trucks (such as heavy duty gas, heavy duty diesel, light duty) affected by the regulation. The draft analysis of EPA interim high altitude standards for light duty vehicles and trucks provided a price elasticity of -.35 for model years 1982 and 1983. There is no reference to a source. It is also not clear whether these are long or short term price elasticities. The DOT assessment of fuel economy standards for passenger cars used a first year price elasticity of -1.52 based on the Wharton EFA Motor Vehicle Demand Model. Thus, this DOT analysis assumes that changes in retail prices have a stronger impact on consumer demand for passenger cars than the draft EPA analysis of interim high altitude standards assumes for light duty vehicles. Furthermore, this DOT analysis, unlike all others, utilized the concept of "net price elasticities." This concept, as defined in the analysis, refers to the behavior of consumers who postpone purchases for only a year or two and then return to the market. Therefore, instead of a constant price elasticity of demand, an annually increasing price elasticity was used for four sequential model years.

PART III: TECHNOLOGICAL INNOVATION

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5.0 Emissions Control R&D and Federal Regulations

5.1 Overview

This section examines the impact of Federal emissions control regulations on innovation in the automobile industry. For the purposes of this paper, we will examine the impact of Federal regulations on the manufacturers of automobiles. We have not included the impact on parts manufacturers or parts and materials suppliers in our investigation.

There is little disagreement that Federal mobile source emissions control regulations required manufacturers of automobiles to undertake large investments over the last decade that they would not have otherwise made. Corporate executives have testified on many occasions that the costs of Government regulations place a great burden on their corporations, and furthermore that the costs of auto emissions controls account for a large share of the total costs of Federal regulations. For example, General Motors has indicated that expenditures for auto emissions controls accounted for about 33 percent or $719 million of the cost of Government regulation to that company in 1980.[21]

A review of production specifications since the early 1960s clearly reveals that automobile manufacturers introduced emissions control systems in response to Federal regulations. The legislative history of the Clean Air Act Amendments explicitly indicates that Federal mobile source emissions control legislation was designed to force industry to develop low emissions automobiles.[22] The first federal regulations were promulgated in 1966 for 1968 and 1969 model year vehicles. Emissions control regulations have become progressively stricter through model year 1981. In response to the increasingly stringent regulations, emissions control systems evolved from various types of simple engine modifications in 1968 (calibrated carburetors, spark-timing and temperature control, and air intake preheaters) to sophisticated mechanical and electronic devices (three-way catalysts with sensors) in 1981.

There is little conclusive evidence to indicate when various automobile emissions control technologies were first developed and available for mass production. The Congressional record since early 1970 demonstrates that EPA, Congressional committees, independent foundations, and automobile industry representatives frequently disagreed concerning the state of technological development and the future feasibility of emission control technologies.[23] Without access to the engineering reports and product development evaluations prepared by the major automobile manufacturers, it is not possible to identify precisely when emissions control technologies were (1) first developed, (2) ready for mass production, and (3) capable of meeting the prescribed emissions levels over the useful lifetime of the equipment. Without this information, it is difficult to link industry technological developments and the evolution of Federal regulatory standards.

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[21] 1981 General Motors Public Interest Report, General Motors Corporation, April 15, 1981.

[22] See for example, Clean Air Act Amendments of 1976, Report by the Committee on Interstate and Foreign Commerce, Section 202 and 203 - Extension of Transportation Controls and Light Duty Emission Standards Committee Proposal, May 15, 1976.

However, it is possible to identify the level of resources committed to R&D for emissions controls technology by the domestic automobile industry since 1967. If we make the reasonable assumption that the level of R&D expenditures is related to the rate of technological innovation, then we can compare the level of R&D expenditures--a proxy for technological innovation--with the promulgation of Federal emissions standards. That is, if we are hypothesizing that strict Federal standards (or the expectation of strict Federal standards) induced or "forced" technological development, we should be able to test this hypothesis by tracking the level of industry R&D expenditures over time against the chronology of expected and actual Federal emission standards.

The legislative history since 1966 suggests that there were two periods when political and legislative developments indicated that the automobile industry expected that Federal emissions standards would not be modified to require stricter controls or new technologies.[24] If the automobile industry in these two periods did indeed expect that future emissions regulations would not be "technology forcing," then we should observe a significant decrease in R&D expenditures for emission control during these periods. There were also two periods when political and legislative developments indicated that the automobile industry expected that strict Federal standards would be promulgated. If the automobile industry in these two periods did expect that future emissions regulations would be "technology forcing," then we should observe a significant increase in R&D expenditures for emissions controls during these periods.

We note that there are other factors that may have influenced investments in emissions control R&D, including: market demand, foreign competition, and fuel prices. Our analysis does not attempt to isolate these factors.

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[23] For examples of different opinions concerning the ability of domestic manufacturers to meet Federal emissions tandards, see Report of the Conference on Air Quality and Automobile Emissions, National Academy of Sciences, June 5, 1975, p. 1; Decision of the Administrator, U.S. Environmental Protection Agency, March 5, 1978, p.8; and the Ford Motor Company Testimony of March 1975 before the Committee on Interstate and Foreign Commerce.

[24] See Retrospective Analyses of Cost Estimates for EPA Automobile Emissions Control Regulation: 1970 to 1981, Appendix D, ICF Inc., May 1981.

5.2 Legislative History

The Department of Health, Education, and Welfare (HEW) promulgated Federal exhaust emission standards for 1968 and 1969 model years in June 1968.[25] In the 1950s, the industry was investigating approaches to exhaust emissions controls. From 1957 to 1964 considerable work had been conducted on the catalytic converter.[26] [27] However, work appeared to stop in 1964 when it became evident that engine modifications and air injection approaches were adequate to meet the anticipated Federal standards. Serious efforts were not resumed until 1969 when hearings on the 1970 amendments proceeded and stricter standards became imminent. In 1969, General Motors announced plans to reinstate its catalyst development program.[28] By November of 1970 (35 FR 17288), HC and CO emissions standards were promulgated for model years 1972 through 1974. NOx emissions standards were first promulgated in June of 1971 for model years 1973 and 1974.[29] These standards were more stringent than the standards promulgated for earlier model years. After a lull in Federal regulatory activity culminating in reductions in emission control R&D activities (starting in 1964), it became apparent in 1970 that strict Federal emissions regulations would once again be promulgated. We would expect to see increases in expenditures for emissions control R&D in the manufacturers' part year 1970 budget and their full year 1971 budget.

Prior to the passage of the 1970 Amendments to the Clean Air Act, exhaust emissions standards were set on the basis of "economic and technical feasibility" as required under the Clean Air Act Amendments in 1965.[30] That is, the standards applicable to model years 1970 to 1974 were based on control levels that could be achieved through the application of current technology requiring little new R&D. Standards were promulgated, in effect, as the control technology became available. Therefore, the mandated levels of control of mobile source emissions were based primarily on existing technological capabilities and did not require major R&D initiatives preceding 1970 model year production.

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[25] See 33 FR 8304, June 4, 1968.

[26] U.S. Congress. Senate. Committee on Public Works. Air Pollution - 1967 (Air Quality Act), Hearings Before the Subcommittee on Air and Water Pollution on S. 780, Parts 2 and 4. 90th Cong., 1st Session, 1967.

[27] U.S. Congress. Senate. Committee on Public Works. Implementation of the Clean Air Act - 1975, Hearings Before the Subcommittee on Environmental Pollution, Parts 3-4, Serial No. 94-H10. 94 Cong., 1st sess., May 1975.

[28] U.S. Congress. Senate. Committee on Public Works. The Impact of Auto Emission Standards, Report of the Subcommittee on Air and Water Pollution.

[29] See 36 FR 12652, June 29, 1971.

[30] The 1965 Amendments to the Federal Clean Air Act gave the Secretary of Health, Education, and Welfare the authority to control emissions from motor vehicles. This authority was transferred to the Administrator of the U.S. Environmental Protection Agency in 1970.

In 1970, however, Congress abandoned the "technical and economic feasibility" approach and set emissions levels for 1975 and 1976 model years based instead upon what was considered to be the level of control needed to insure the attainment of health-related air quality levels determined by the National Air Pollution Control Administration of the Department of Health, Education and Welfare. Although the 1970 Amendments did not specify (or did not direct the EPA Administrator to specify) the type of control technology to be developed to meet the 1975 and 1976 standards, the requirements of the 1970 Amendments did compel industry to accelerate research and development activities in the area of emissions control. To this extent, the requirements of the 1970 Amdnements were intended to be "technology-forcing." The time period by which the standards were to be met was based upon consideration of the lead time requirements of industry.[31] The pace of technological development between 1970 and 1973 was reported by EPA to be promising.[32] [33]

EPA issued standards reflecting the 1970 Amendments' legislative mandate for 1975 and 1976 models in July of 1971.[34] However in April of 1973, the EPA Administrator granted the first 1-year suspension of the 1975 standards and established interim standards. Furthermore, in 1973, Congressional hearings were held to consider suspension of the 1976 NOx standard as Congress considered the need for fuel economy initiatives. In July of the same year, suspension was granted for the 1976 model year standards. We would expect to see increases in manufacturers' expenditures for emissions control R&D in manufacturers' part year 1973 R&D budget and full year 1974 budgets.

In 1975, the EPA Administrator recommended a delay until 1982 for meeting the more stringent (.41/3.4/2.0) standards based on the potential adverse health impact of sulfate emissions. He further recommended extending the 1977 interim standards in effect until 1979. Shortly after the Administrator's recommendation, industry asked for a 5-year freeze on the standards at the 1975 interim levels. Industry representatives argued that this so-called "productive pause" was necessary to allow manufacturers to focus attention on fuel economy improvements, to re-evaluate the sulfate emissions problem, to restore jobs in the automotive industry, to slow down inflation by holding down the cost of automobiles, and to investigate alternate emissions control systems or engines which could in the long run more effectively and efficiently reduce HC/CO/NOx emissions than could the current technology. In 1976, Congress was expected to pass amendments to the Clean Air Act which would delay the emissions requirements at least through 1978. However, a filibuster in the Senate prevented passage and Congress adjourned without the legislation. At this point, the promulgation by EPA of regulations requiring emissions control systems beyond the level of current technology appeared doubtful. Therefore, as early as 1974 the industry was not expecting EPA to promulgate regulations requiring emissions control technologies. We would expect this to have a significant impact on the industry's plans for R&D activities after 1975.

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[31] U.S. Senate, Report of the Committee on Public Works to Accompany S. 4358 National Air Quality Standard Act of 1970, p. 27, September 1970.

[32] U.S. Environmental Protection Agency. Automobile Emission Control - The Technical Status and Outlook as of December 1974. National Technical Information Service Pubn. No. 217-116. February 1973.

[33] U.S. Environmental Protection Agency. Automobile Emission Control - The Technical Status and Outlook as of December 1974. National Technical Information Service Pubn. No. 250-691. January 1975.

[34] See 36 FR 1257, July 2, 1971.

In August 1977 Congress amended the Clean Air Act. The 1977 standards were held over through 1979; the standards for 1980 and 1981 were established.[35] In fact, the 1981 HC and CO standards were established at the stringent levels originally promulgated for model year 1975 in 1971 following the 1970 amendments. Therefore, by the late 1970s, it became clear once again that industry would be required to meet strict model year 1980 and 1981 standards. The actions taken by Congress in 1977 would have a significant impact on the industry's 1978 plans.

The legislative history outlined above identifies two periods in which it appeared that Federal regulations would not require technological innovation (R&D) and two periods when it appeared that Federal regulations would require technological innovation, as summarized in Exhibit 5.1.

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[35] On August 7, 1977, the Clean Air Act Amendments of 1977 were signed (PL 95-95). Emissions standards for model years 1978 through 1982 were published on August 11, 1977 (42 FR 40697), August 24, 1978 (43 FR 37972), September 25, 1978 (43 FR 43299), and December 7, 1978 (43 FR 57253).

EXHIBIT 5.1

EXPECTATIONS FOR FUTURE EMISSIONS CONTROLS REGULATIONS AND INVESTMENTS IN R&D FOR EMISSIONS CONTROLS 1964 TO 1980

	Period	Industry Expectations for Future Emissions Control Regulation	Expected Level of Investment in Emissions Control R&D
Period I	1964-70	status quo	low
Period II	1971-73	stricter standards (technically and economically feasible)	high
Period III	1974-77	status quo	low
Period IV	1978-80	stricter standards (technology forcing)	high

Furthermore, Congress adopted a strong "technology forcing" policy with the 1970 Amendments to the Clean Air Act. We would, therefore, expect to see a more substantial R&D effort after the promulgation of regulations implementing the Clean Air Act Amendments of 1970 (Periods II, III and IV) than before their promulgation (Period I).

5.3 R&D Expenditures

This section presents estimates of total R&D expenditures by domestic automobile manufacturers from 1967 to 1981 and the component of those expenditures dedicated to emissions controls. These estimates were derived primarily from industry data provided to EPA or presented in company public interest and financial reports. Our estimates of emissions controls research and development expenditures do not include expenditures for facilities and tools and do not include industry expenditures for "lobbying" or public policy development activities. R&D expenditures estimates are summarized in Exhibit 5.2 along with other measures of the manufacturers' commitment to R&D expenditures for emissions controls. The data summarized in Exhibit 5.2 are presented in Exhibit 5.3.

EXHIBIT 5.2
(SAME AS EXHIBIT 2.3)

SUMMARY OF R&D EXPENDITURES FOR EMISSIONS CONTROLS BY DOMESTIC AUTOMOBILE MANUFACTURERS* FROM 1967 TO 1980

	Period	Expected Level of Investment in Emissions Control R&D	Actual Annual Average Expenditures for Emissions Control R&D (millions of 1980$)	Expenditures for Emissions Controls R&D as a Percentage of Sales
Period I	1967-70**	low	186	0.2
Period II	1971-73	high	571	0.5
Period III	1974-77	low	559	0.4
Period IV	1978-80	high	672	0.5

*General Motors Corporation, Ford Motor Company, Chrysler Corporation, American Motors Corporation.

** We were not able to prepare estimates for 1964 through 1966.

The data presented in Exhibit 5.2 tend to support our hypothesis. For the two periods for which we anticipated a low level of investment in emissions R&D (Period I prior to 1971 and Period III, from 1975 to 1977), we observe a relative decline in emissions control R&D expenditures. The annual average expenditures for these two periods are $186 million and $559 million respectively. This is lower than the level of investments following and preceding each of these periods. The decline in emissions controls R&D expenditures from Period II to Period III was not dramatic--about 2 percent. However, the increases in R&D expenditures over the prior periods in Period II and Period IV were dramatic--300 percent and 20 percent respectively.

EXHIBIT 5.3

R&D EXPENDITURES FOR THE DOMESTIC AUTOMOBILE MANUFACTURERS*
1967 TO 1980

(millions of 1980 dollars)

	Period I 1967 to 1970				Period II 1971 to 1973			Period III 1974 to 1977				Period IV 1978 to 1980		
Year	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Total R&D	1,812	1,996	2,187	2,315	2,854	3,713	4,324	4,064	3,154	3,558	4,011	4,408	4,641	4,245
Emissions Control R&D	110	142	214	276	461	519	732	546	596	561	531	638	736	643
Emissions Control R&D as a Percentage of Sales	.12	.13	.21	.32	.43	.44	.57	.50	.46	.35	.35	.41	.52	.60

*Aggregate estimates based on estimates for General Motors Corporations, Ford Motor Company, Chrysler Corporation, and American Motors Corporation.

Source: Author's estimates based on: A Review of the Good Faith of the Automobile Industry in Attempting to Comply With the Statutory 4.0 NOx Standard. A Report to the Senate Public Works Committee, U.S. Congress, U.S. Environmental Protection Agency, May 9, 1975; 1981 General Motors Public Interest Report, General Motors Corporation, April 15, 1981; Financial Characteristics of Motor Vehicle and Equipment Manufacturers, Information Handbook, (1981 Edition), Motor Vehicle Manufacturers Association of the United States, Inc., February 1981; WARD's 1971 Automotive Yearbook, Ward's Communications, Inc., 1971; company Annual Reports on Form 10-K and Annual Reports (1967, 1968, 1969, 1980).

We examined R&D expenditures as a percentage of sales to determine if R&D expenditures were correlated to the business cycle or sales trends. If our hypothesis is valid, we should also observe increases in R&D expenditures as a percentage of sales in Periods II and IV. This would indicate that R&D expenditures represented a larger proportion of available resources in these two periods independent of total sales levels or fluctuations. Emissions R&D expenditures as a percentage of sales increased in periods II and IV and decreased in periods I and III. This indicates that the domestic industry committed less of its available resources to emissions R&D in periods I and III when it did not anticipate further increases in Federal emissions control regulations, and more in periods II and IV when it did anticipate further increases in Federal emissions control regulations.

As anticipated, annual average emissions control R&D expenditures during the low activity phase in Period I (prior to the 1970 Clean Air Act Amendments) were significantly lower than during the low activity phase in Period III. This reflects the change of policy in the 1970 Clean Air Act Amendments from standards based on available technology to standards designed to force technological innovation. After the 1970 Clean Air Act Amendments, annual average expenditures for emissions control R&D were $586 million. This is three times greater than the annual average expenditures for emissions control R&D from 1967 through 1970 of $186 million. This represents an increase in the percentage of sales dedicated to emissions controls R&D from 0.2 percent to 0.5 percent.

5.4 Comments

The pattern of estimates of expenditures for emissions control research and development activities by domestic automobile manufacturers since 1967 tends to support our hypothesis--that Federal emissions control regulations induce investments in R&D activities which lead to technological innovation. There are three analytical points that we would like to highlight.

First, this analysis does not address R&D conducted by automobile parts manufacturers and suppliers. Firms that provide emissions control systems to the four large automobile manufacturers conduct research and development activities leading to technological innovation in materials sciences, production methods, and component design that are applicable to many industries. The effect of Federal regulations on these parts manufacturers and parts suppliers should be addressed to provide a complete assessment of the effect of Federal emissions control regulations on technological innovation.

Second, automobile manufacturers frequently contract with other companies and institutions for research and development activities. It is not unusual for these outside contracts to account for as much as a third of a company's total annual emissions control expenditures. This analysis addresses only expenditures for R&D conducted by the automobile manufacturers themselves. It does not include expenditures for R&D contracts with other firms or institutions.

Third, this analysis is based on data developed by the automobile manufacturers. We have not confirmed the manufacturers' estimates based on an independent review.

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APPENDIX A

STANDARDIZED BASELINE PROCEDURES

Six initial adjustment procedures were applied to data taken from the nine studies considered in this report. To standardize the baseline assumptions for all studies we generally chose the assumptions used to prepare the Cost of Clean Air 1979. This is not because CC79 necessarily represents the most analytically sound study, but rather because it was the latest and the most complete of the nine studies. In fact, in some ways CC79 is not a desirable study to use as a benchmark, because many of the key assumptions used in preparation of the report were not documented in the test of the report, but were reconstructed with the help of EPA for purposes of this study. Using a standard baseline provides a common denominator to all nine studies, so that the dollar values of the four cost components are comparable.

Cost estimates for each study were recalculated using the same assumptions for three key parameters: price of gas, average fleet MPG, and hardware configuration.

1) Price indexing: All costs were deflated to 1967 dollars, using the annual average Overall Consumer Price Index.

2) Deannualization of maintenance, fuel penalty, or unleaded costs: Whenever costs were expressed in a study as a cost per year they were converted to lifetime costs. That is, annual costs were multiplied by a factor of 10 to obtain the lifetime costs.

3) Grade of gasoline. The price of regular leaded gasoline was used in fuel consumption penalty calculations. If a study in its own calculation of the fuel penalty used the price of unleaded gasoline, the numbers were recalculated using the price of leaded gasoline, to eliminate any unleaded price penalty effect on the fuel consumption penalty.

4) Price of gas. The price of gasoline chosen by a study has a significant influence on the dollar value of the fuel consumption penalty. The point of this study, however, is not to analyze the gasoline price effects on fuel penalty costs, but to analyze the real differences in the estimated fuel penalty. The price of gasoline is affected by factors extraneous to the costs of meeting pollution control standards. For this reason, all studies were adjusted so that the price of gas used in the fuel penalty calculation was $.50 in 1967 dollars.

5) MPG. The MPG of the new car fleet for the model year under consideration has a significant influence on the dollar value of the fuel consumption penalty and the dollar value of the unleaded penalty. It was not possible to prepare standard estimates of the cost associated with fuel penalties with the assurance that the common base MPG would be accurate. The base MPG assumptions (and the current fleet MPG assumptions) and fuel penalties derived from these assumptions are intimately related.

6) Hardware Configuration. Estimates that use a post-1967 model year baseline will naturally have lower hardware cost estimates than studies with a model year 1967 baseline. This is because the costs of the early years of pollution control standards are included in the baseline, not in the incremental cost estimates. Because the purpose of this study is to analyze the differences between hardware costs, and not residual effects due to baseline assumptions, the hardware costs are standardized to a common baseline.

Hardware costs were standardized as follows. The costs estimated by CC79 up to the baseline of the study are added directly to the unadjusted hardware costs. A simple example will make this process clear: If a study has a 1970 model year baseline and estimates incremental hardware costs to be $100 for the 1972 model year, then the cost adjusted for baseline differences would include both the $100 for the 1972 model year and the amount CC79 estimated for up to model year 1970.

APPENDIX B

SUMMARY OF SALES PROJECTIONS BY MODEL YEAR AND VEHICLE TYPE

APPENDIX B

SUMMARY OF SALES PROJECTIONS BY MODEL YEAR AND VEHILCE TYPE [1]

(millions of vehicles)

Vehicle Type	Agency	Regulatory Activity	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Light Duty Vehicles	DOT	Fuel Economy Standards for 1981-1984 Passenger Cars	11.000	11.400	10.900	11.100						
	DOT	Improving Comfort and Convenience of Seat Belt Assemblies		11.800	12.000	12.200						
	EPA	Interim (1982-1983) High Altitude Emission Standards for Light Duty Vehicles		10.086	11.314							
	DOT	Rearview Mirror Systems					13.500[2]					
	DOT	Fields of Direct View					13.500[2]					
Light Duty Trucks	DOT	Fuel Economy Standards for Model Year 1982 Light Trucks		2.600								
	EPA	Interim (1982-1983) High Altitude Emission Standards for Light Duty Vehicles		2.800	3.200							

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[1] These are the projected sales levels unadjusted for any change in consumer demand which may occur as result of additional costs of regulation.

[2] Estimate made for "mid-1980's"

APPENDIX B (continued)

SUMMARY OF SALES PROJECTIONS BY MODEL YEAR AND VEHILCE TYPE 1/
(millions of vehicles)

Vehicle Type	Agency	Regulatory Activity	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Light Duty Trucks (cond't)	EPA	HC and CO gaseous Emissions Regulations for 1984 and Later Model Light Truck			2.460	1.690	2.820	2.840	2.830			
	DOT	Rearview Mirror Systems					2/3/ 4.200					
	DOT	Fields of Direct View					2/3/ 4.200					
Light Duty Vehicles and Trucks	EPA	Light Duty Diesel Particulate Standards		15.893	16.213	16.537	16.868	17.208	17.545	17.898	18.257	
Light Trucks and Multi-purpose van	DOT	Occupant Protection in Interior Impacts		3.800								
	DOT	Hydraulic Brake Systems			3.825							
	DOT	Improving Comfort and Convenience of Seat Belt Assemblies		3.026	3.026	3.026						
	DOT	Rearview Mirror Systems					2/ 4.448					

1/These are the projected sales levels unadjusted for any change in consumer demand which may occur as result of additional costs of regulation.

2/Estimate made for "mid-1980's"

3/This estimate was made for a larger size class of vehicles--vehicles with a 10,000 lbs. GVWR or less. Other sales estimates of the same vehicle type were made for vehicles less than or equal to 8,500 lbs. GVWR.

APPENDIX B (continued)

SUMMARY OF SALES PROJECTIONS BY MODEL YEAR AND VEHILCE TYPE 1/
(millions of vehicles)

Vehicle Type	Agency	Regulatory Activity	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
	DOT	Direct Fields of View					2/ 4.488					
Light Duty Diesels (Vehicles and Trucks	EPA	Light Duty Diesel Particulate Standards		1.192	1.443	1.571	1.923	2.374	2.895	3.150	3.414	
Heavy Duty Vehicles	EPA	Federal Noise Standards for Medium and Heavy Trucks		4/ .479		4/ .507						
	DOT	Rear View Mirror Systems				4/ .400						
	DOT	Fields of Direct View				2/4/ .400						
	EPA	HC and CO Gaseous Emission Regulations for 1984 and Later Model Year Heavy Duty Engines				.633	.645	.657	.669	.681	.693	
	EPA	Heavy Duty Diesel Particulate Regulations					.645	.657	.669	.681	.693	.705

1/These are the projected sales levels unadjusted for any change in consumer demand which may occur as result of additional costs of regulation.

2/Estimate made for "mid-1980's"

4/This estimate made for a smaller size class of vehicles--vehicles with a 10,000 lbs. GVWR or more. Other sales estimates of the same vehicle type were made for vehicles more than or equal to 8,500 bls. GVWR.

APPENDIX B (continued)

SUMMARY OF SALES PROJECTIONS BY MODEL YEAR AND VEHILCE TYPE 1/

(millions of vehicles)

Vehicle Type	Agency	Regulatory Activity	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Heavy Duty Diesel Vehicles	EPA	HC and CO Gaseous Emission Regulations for 1984 and Later Model Year Heavy Duty Engines				.266	.284	.302	.321	.341	.360	
	EPA	Heavy Duty Diesel Particulate Regulation					.284	.302	.321	.341	.360	.381
Heavy Duty Gasoline Vehicles	EPA	Heavy Duty Evaporative Emissions Standards and Procedures			.458	.465	.471	.478	.485			
	EPA	HC and CO Gaseous Emission Regulations for 1984 and Later Model Year Heavy Duty Engines				.367	.361	.354	.347	.340		

1/These are the projected sales levels unadjusted for any change in consumer demand which may occur as result of additional costs of regulation.

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APPENDIX C

GRAPHIC PRESENTATION OF TOTAL COST ESTIMATES AND COMPONENTS OF TOTAL COST ESTIMATES BY STANDARD BY MODEL YEAR

The total cost estimates and components of total cost estimates are graphically presented in this appendix for the standards for model years 1970, 1972, 1973, 1975, and 1980.

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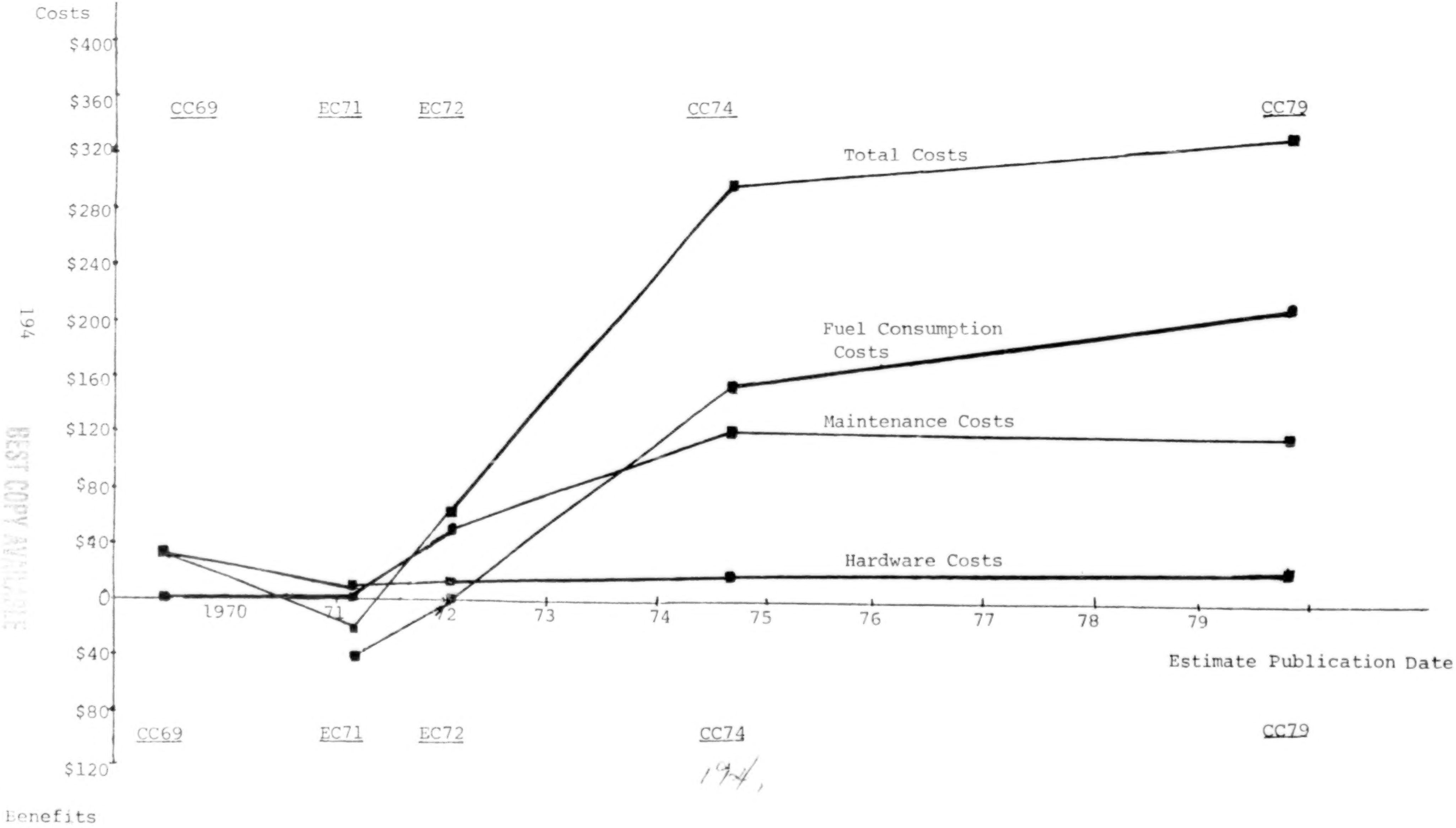
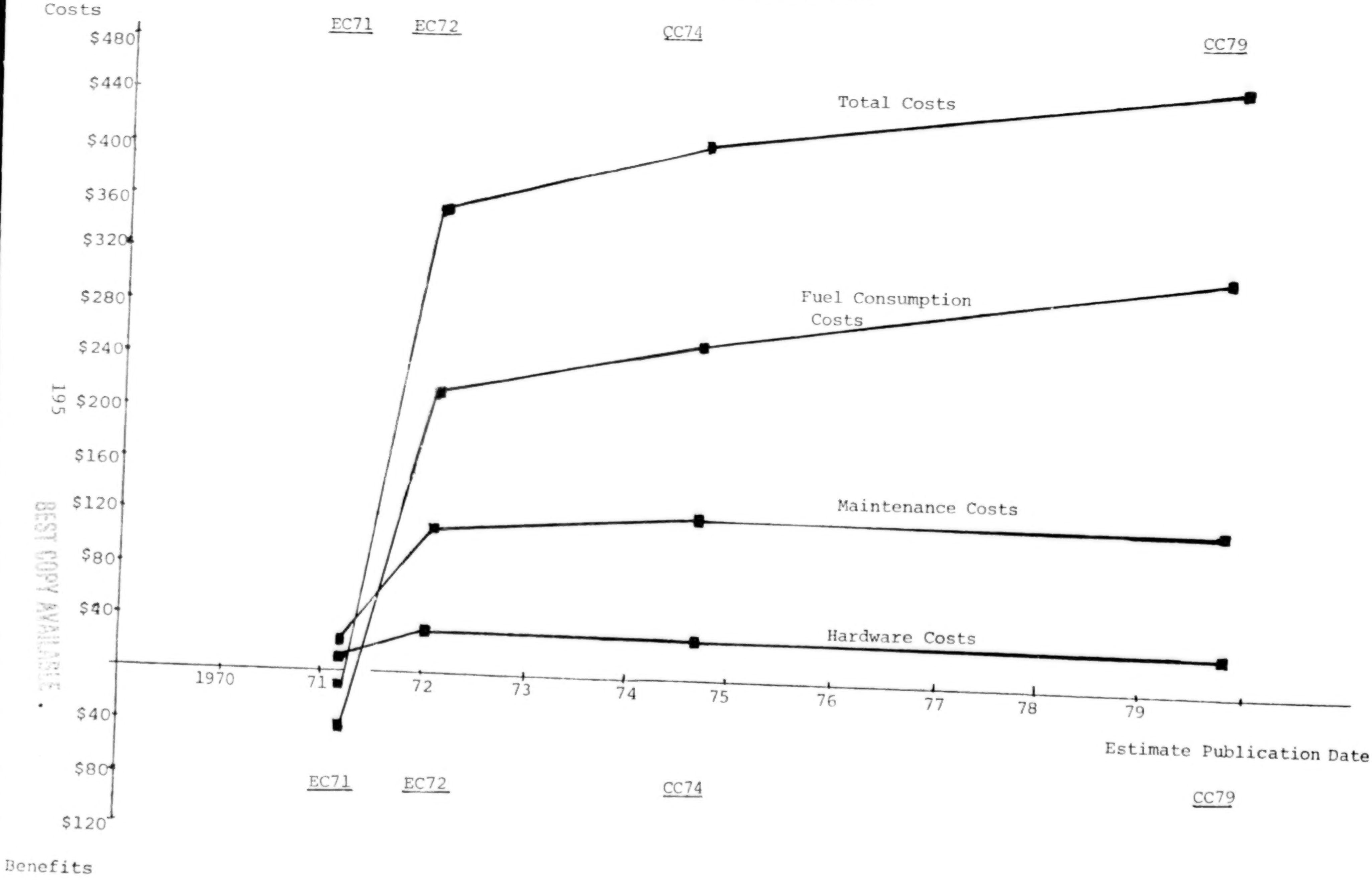
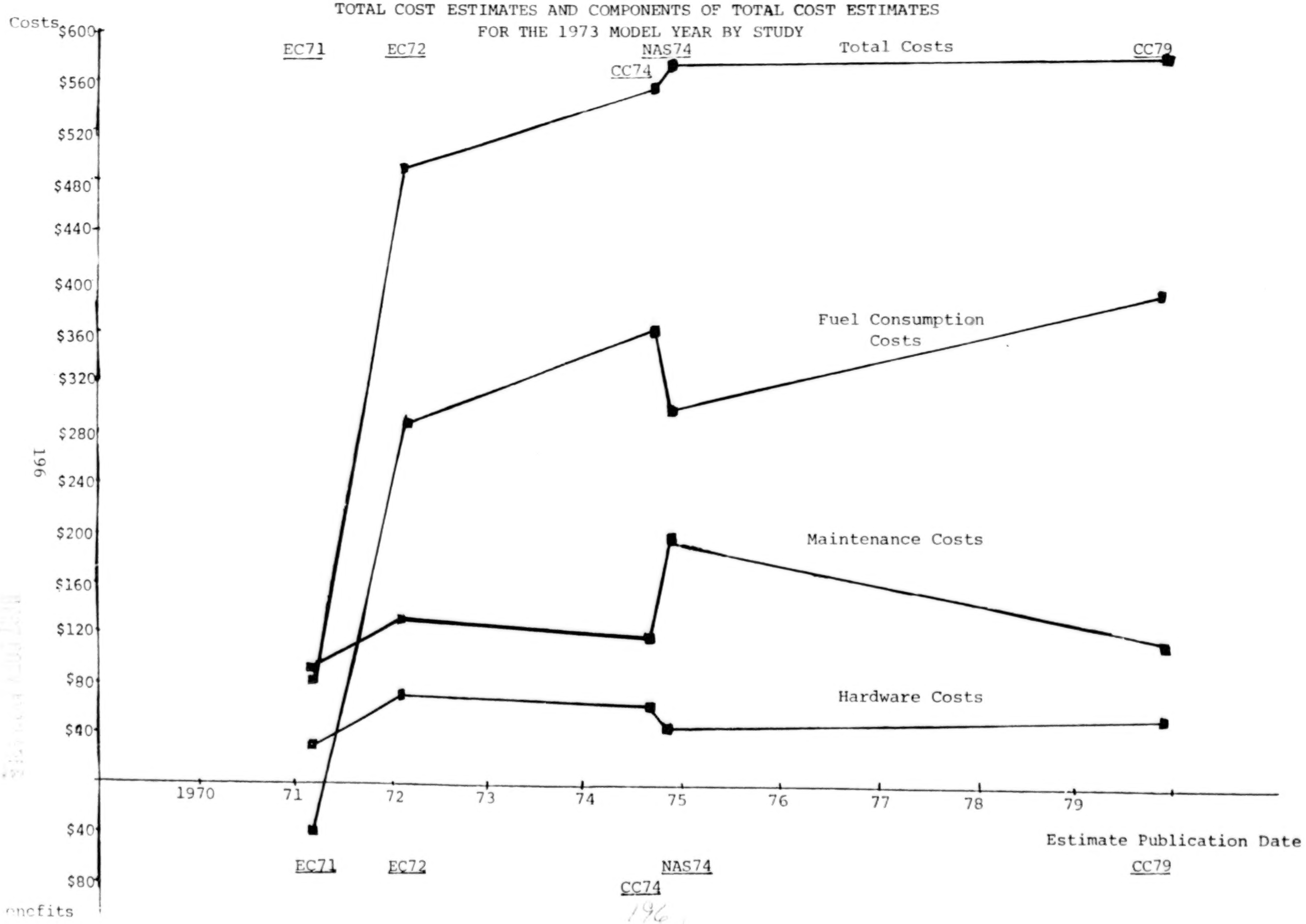
TOTAL COST ESTIMATES AND COMPONENTS OF TOTAL COST ESTIMATES FOR THE 1970 MODEL YEAR



TOTAL COST ESTIMATES AND COMPONENTS OF TOTAL COST ESTIMATES
FOR THE 1972 MODEL YEAR BY STUDY

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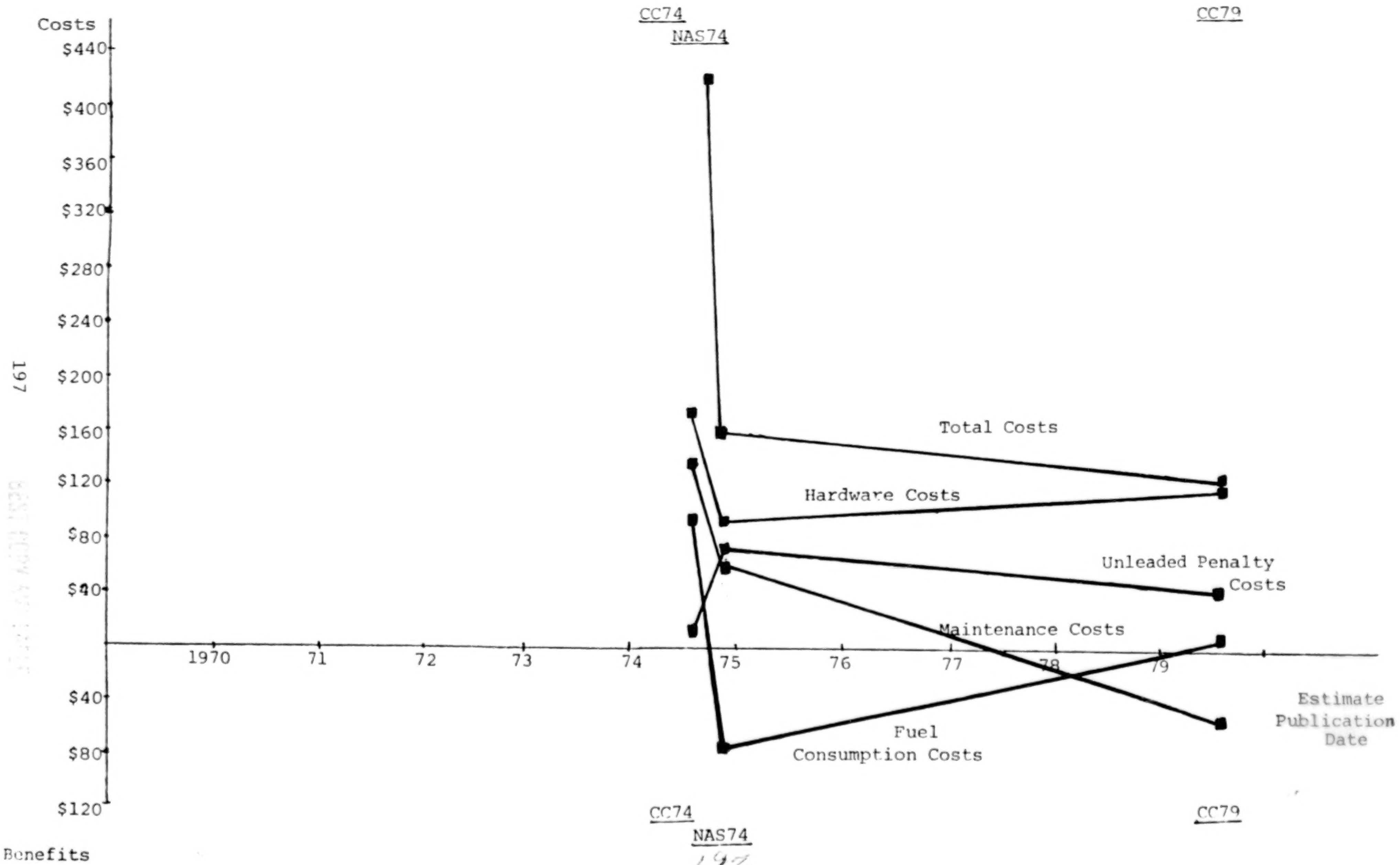
FOR THE 1973 MODEL YEAR BY STUDY

TOTAL COST ESTIMATES AND COMPONENTS OF TOTAL COST ESTIMATES FOR THE 1975 MODEL YEAR BY STUDY



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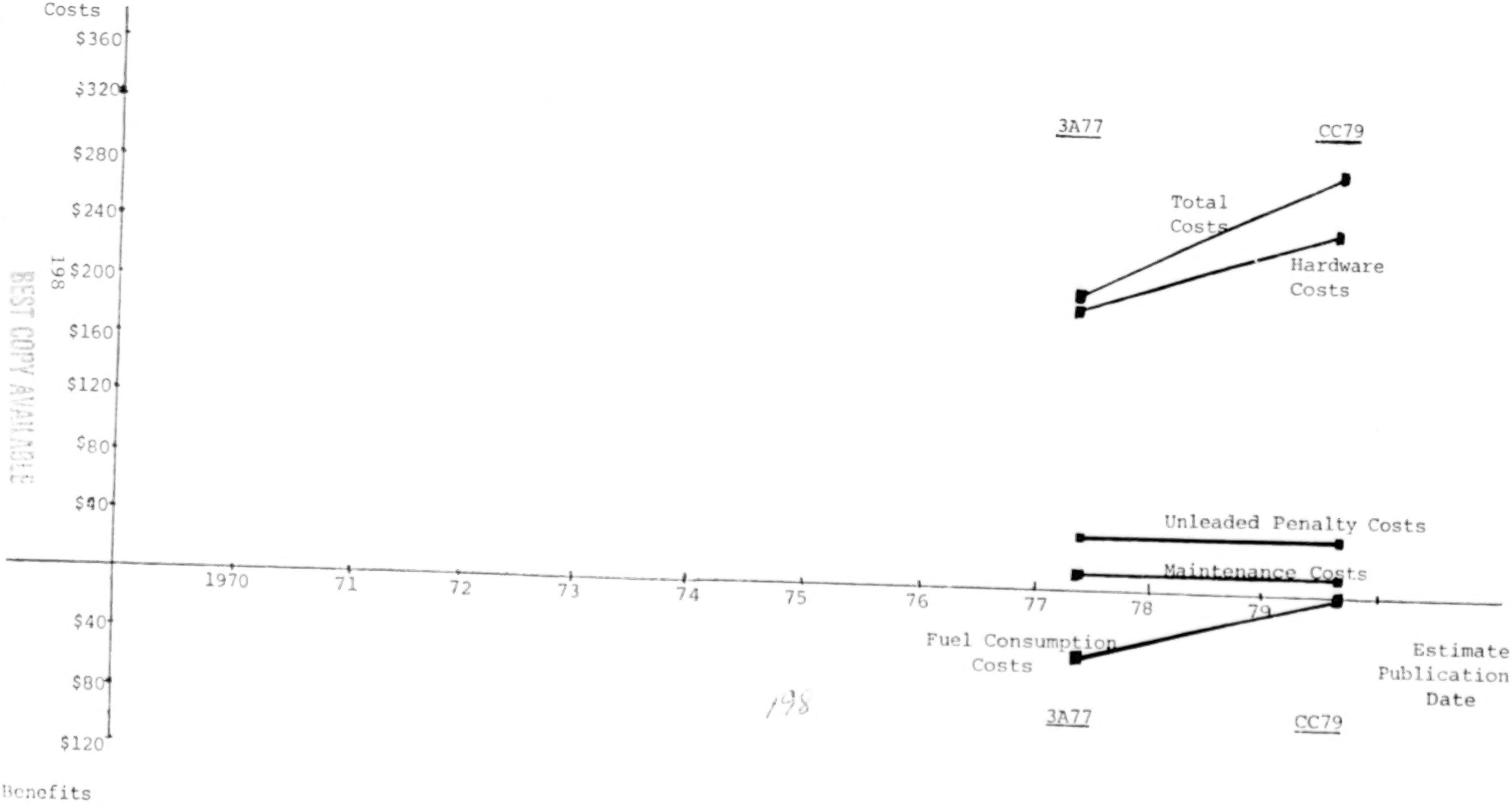
TOTAL COST ESTIMATES AND COMPONENTS OF TOTAL COST ESTIMATES
FOR THE 1980 MODEL YEAR BY STUDY



APPENDIX D

REGULATIONS ADDRESSED IN SECTION 3.0

This Appendix summarizes the regulatory activities included in The Automobile Calendar that are addressed in Section 3.0 of this report. They include motor vehicle regulations under development by EPA and DOT as of January 1981.

EPA Regulatory Activities

Automobile and Light-Duty Truck Surface Coating Operations Standards of Performance

Alternative Durability Program

Federal Refueling Hydrocarbon Control Requirements

Fuels and Fuels Additives

Heavy-Duty Diesel Particulate Regulations

Heavy-Duty Evaporative Emissions Standards and Procedures

High Altitude Emission Standards Beginning with 1984 Models

High-Altitude Performance Adjustments

HC and CO Gaseous Emissions Regulations for 1984 and Later Model Year Heavy-Duty Engines

HC and CO Gaseous Emissions Regulations for 1984 and Later Model Year Light-Duty Trucks

Interim (1982-83) High-Altitude Emission Standards for Light-Duty Vehicles

Light-Duty Diesel Particulate Regulations

0.4 Oxides of Nitrogen Demonstration Car Standard

Oxides of Nitrogen Emission Regulations for 1985 and Later Model Year Light-Duty Trucks and Heavy-Duty Engines

Short Tests for Emission Warranties

Emission Control Design and Defect Warranty

Federal Noise Standards for Medium and Heavy Trucks (1982)

Importation of Motor Vehicles and Motor Vehicle Engines

Nonconformance Penalties for 1984 and Later Model Year Heavy-Duty Engine Emissions

Commercial and Industrial Use of Asbestos Fibers

DOT Regulatory Activities

Minimum Cab Space Dimensions

Rear Underride Protection

Automatic Occupant Protection

Battery Explosions

Brake System Inspectability

Child Restraint Systems

Child Restraint Tether Anchorages

Confidential Business Information

Crashworthiness Ratings

Door Locks and Door Retention Components

Extension of Automatic Restraint Requirements

Fields of Direct View

Fuel Economy Standards for Model Year 1981-84 Passenger Cars

Fuel Economy Standards for Model Year 1982 Light Trucks

Fuel Economy Standards for Model Year 1983-85 Light Trucks

Heavy-Duty Vehicle Brake Systems - Long Range Policy

Hydraulic Brake Systems

Improving Comfort and Convenience of Seat Belt Assemblies

Multipiece Rims on Trucks and Buses

New Pneumatic Tires - Passenger Cars

Occupant Protection in Interior Impacts: Impact Protection for the Driver from the Steering Control System

Pedestrian Protection

Rearview Mirror Systems

Side Door Strength, Upgrade and Extend Performance Standards

Speedometers and Odometers

Standardized Location for Controls and Displays

Theft Protection Standard

Tire Identification and Recordkeeping

Tire Selection and Rims - Passenger Cars - Reserve Load

END

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